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Nature Study

ONE HUNDRED LESSONS
ABOUT
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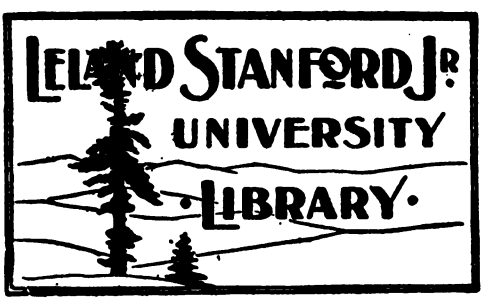

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Fig. 77.
A passion flower. Photographed by the late Dr. J. R. Weist.

NATURE STUDY

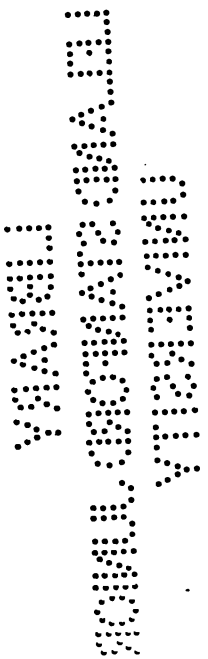
ONE HUNDRED LESSONS ABOUT PLANTS

BY

DAVID WORTH DENNIS,
Professor of Biology in Earlham College.

With More Than One Hundred and Fifty Illustrations.

O. W. FORD & CO.
MARION, IND.



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This Book is Dedicated to all who Are Helped by it.

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PREFACE.

Nature Study is new; Liebig was the first man who used a laboratory for instruction. He began his career as a teacher in 1824.

Courses in mathematics and language have had centuries in which to perfect their methods of instruction and the lessons it is best to offer; for this reason, lessons in these subjects are good, if not the best, that can be offered, and the methods of giving them have had opportunity to eliminate errors. The teacher of nature study has almost no past to guide him. The older teachers of nature study were not themselves taught in schools. As a department of instruction it is without traditions or precedents. Every serious teacher so far has had to pave his own road. All teachers have gone different roads. It could not be otherwise.

The material with which nature study deals, is inexhaustible; no one can ever be acquainted with more than an insignificant fraction of it. It is all good. It will always be the case that successful teachers will give what they know. They will accordingly teach different things. It is probably true that every successful teacher has, from year to year, taken his pupils over different ground, and that everything done has proved to be good. What it is best to teach we cannot yet tell, in other words, than that that material is best which can be had.

This nature study work has passed through three phases. It was first taught from books. The only nature study work I ever did in school was in Geography and Physiology and every syllable of these came from books. We next added the laboratory. How new this phase of the subject is, may be learned from the presidential address of Dr. Wiley before the Indiana Science Teachers' Association at Lafayette, in 1895. He says: "Prior to 1863 no laboratory instruction was given in Indiana except a little in qualitative analysis."

Much has come from the laboratory as a means of instruction. But we had not been trying it long when we learned that though the laboratory, like the book, is a great help, still it is not enough. Aristotle had set us our task; Zoology has its end not in what an animal is or what it does, but why it does it. Fitness is the real

Zoology. We had studied the sucker in books and learned much; we brought him to the laboratory and learned more, but the sucker had spots. Why did he grow them? We had to go to the brook for answer; his spots resemble the stones on the bottom of the stream. He grew them in imitation of this bottom, and he thus often escaped his enemies. This brought us to the third phase, the outing. This is now in full swing; nature study of whatever degree cannot do without it. The Gulf Stream and the Rocky Mountains we cannot take to the school, but we can and do take the school to them.

It is now known that nothing we ever did was wholly wrong. The book, the laboratory, the outing, all were necessary. This book emphasizes the outing, but contemplates the use of book and laboratory as well.

The outing, to be sucessful, must have a definite purpose and nearly all the lessons and exercises here given hold up one thing to be learned.

This one thing should be important. The teacher and pupil alike should be able to see that the lesson is worth while. Terms incidentally necessary to the learning of the lesson should be acquired by use first. Let definitions wait until they are needed. The excuseless thing that nature study has done is: it has piled up definitions of parts, forms, disguises, etc., by the hundreds of pages and has turned t..em on in installments, away from what they represent and apart from any possible use that the learner could see. This book has been written with the conviction that this ought to stop. If it has left undefined any necessary terms for any lesson, Webster, Worcester or the Century at least, will supply the omission.

It has been the constant aim of these pages to put the student in possession of guiding principles,—something that will help him interpret what he sees. Nearly all the lessons consider, in one form or another, the plant in question as a species that has won in the struggle for existence and they direct attention to the adaptations that have enabled it to win.

It is my conviction that knowledge on the part of the teacher is the chief thing we lack. This consideration has led me to confine these lessons to a field so limited that it would be possible for the faithful teacher to gain the necessary knowledge. I do not see how I could give these lessons without knowing the plants in

question by name. This is the first thing children ask and the best way to induce them to learn the important things the teacher assigns is for him to tell them the unimportant (?) things they ask. These lessons mainly deal with common trees; but a teacher should have a good manual of botany and know how to use it to find the name of a plant. For the Ohio Valley, Gray's Manual is a good one for determining the names of flowering plants. Apgar's Trees of the Northern United States will enable any teacher to find the name of most, if not all, trees by their leaves only. A good general botany is Campbell's University Botany. Three good smaller works are Bailey's Elementary Botany, Coulter's Plant Relations and Plant Structures, and Atkinson's Elementary Botany. The catalogue prices of these books and their publishers, are as follows:

Bailey's Elementary Botany, The Macmillan Co., $1.10.
Coulter's Plant Relations, $1.10; Coulter's Plant Structures, $1.20, D. Appleton & Co.
Atkinson's Elementary Botany, Henry Holt & Co., $1.25.
Campbell's University Botany, The Macmillan Co., $4.00
Apgar's Trees, The American Book Co., $1.00.
Gray's Manual, The American Book Co., $1.65.

A summer term in some lakeside or seaside laboratory, would be of the greatest value to any prospective teacher of nature study. It may be depended upon that in science, with fullness of knowledge, enthusiasm and some good way to teach, will follow.

There is another sort of literature that the teacher should use for the sake of the pupil: Stories and poems by masters that treat directly or indirectly of plants. Only selections should be used that are worthy; that belong to enduring literature. The following list will show the character of the reading to which I refer:

Bryant, "The Yellow Violet," "The Fringed Gentian," "The Death of the Flowers;" Wordsworth, "The Oak and the Broom," "Daffodils"—"I wandered lonely as a cloud," "To the Celandine;" Emerson, "The Rhodora;" Burns, "To a Mountain Daisy;" Dickens, "The Ivy Green;" Holmes, "Album Verses;" Southey, "The Holly Tree;" Santine, "Picciola;" Thoreau, "The Succession of Forest Trees;" Kipling, "The Jungle Books."

In addition to these there are hundreds of other worthy references to plants in the works of all our standard authors, from Shakespeare to Riley. Hunt them up and they are yours.

NATURE STUDY AND THE CHILD.

My last recommendation may be criticised or called sentiment or anything else, so the critic remembers it concerns itself with the child's need; his nature; his demands; the child's imagination is

fairly riotous and must be directed; because poetry and story were the first phases of the world's literary activity, they appeal to the mind of the growing child. Let him have them, part of the time, and let them wed him to his more serious nature study as they are sure to do. It is maintained that the imagination is to be cultivated, but not in connection with nature study. But suppose history teachers fence their preserve the same way? and teachers of religion and sociology?

It has been said that this child preference for poetry, story, myth and the heroic, is a "passing phase"; the tadpole's tail is a "passing phase" but the stronger you make it the further the frog will be able to jump. Let the child enjoy nature study; science can stand it in any event and will gain by it if it helps the child. As his interest in the subject grows, his need of any fanciful presentation will decline.

The child's powers of observation are proverbial; his desire for knowledge is keen; it is universal among normal children; his curiosity leads him to ask questions; disapproval or even punishment will not stop his questioning. He only leaves it off when he despairs of an answer. His impossible questions mean only that his mind is awake and hungry; show him something it is worth while for him to see or tell him something worth knowing and keep this up to the point of weariness; then let him rest; let this go on through the grades and nature study will have done for him its best. How many curious, inquisitive children and how few curious, inquisitive men! Nature study if anything can remedy this. In the past, from the kindergarten or home to the high school or college, our instruction has been almost wholly in books; during this period, the pupil's confidence in his power to see often almost wholly disappears. Ask a class of a hundred freshmen to learn how many gills a crawfish has, and the many will go to the library, the few to the brook. What a blessing nature study would be if it could keep alive throughout the formative period, the child's native desire to know at first hand. It would

give to the race as many Aristotles and Darwins as child endowments promise us.

The child has tasks enough; tasks which he must not only do but remember for the quiz. Why not interest him in something without the imminence of a judgment day. Ten inspiring minutes twice a day and an outing twice a week, when the weather is suitable, with the blessed privilege which men universally enjoy of forgetting if he wants to, will put a spirit into all his tasks that will surprise every one in its results. The one big result will be that learning will become attractive.

I am under obligation to Prof. H. B. Dormer of Purdue, for Figure 30. To Prof. J. F. Thompson of the Richmond High School for Figures 29, 54, and 87, and to Mr. A. M. Mahaffy for Figure 139; to Miss Helen M. Fiske for several drawings and to Mr. George Bond, Mr. Vivian Floyd, Miss Ruth Trueblood and Mr. Charles H. Frazee for permission to photograph microscopic slides; all of these are credited in connection with the several illustrations. A few illustrations have been copied from different sources and are acknowledged in the accompanying cut legends. I am under special obligations to Prof. David M. Mottier of the Indiana University and to Prof. J. F. Thompson of the Richmond, Indiana, High School, who have read all the proof. Their suggestions have been very valuable and I have been able to turn them all to account. I assume all responsibility, however, for both the subject matter and the method of presenting it.

I take pleasure in adding to the list of books given on page VII of this preface at Prof. Mottier's suggestion, Stevens's Introduction to Botany. D. C. Heath & Co.

DAVID WORTH DENNIS.

Earlham College, June, 1903.

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NATURE STUDY.

ONE HUNDRED LESSONS ABOUT PLANTS.

LESSON I.

ADAPTATION TO LIGHT.

The Disposition of the Branches of a Beech Tree.

Figure 1 shows a beech tree in its winter condition. It will be noticed that its lower branches droop; higher up they are horizontal; higher still they rise. Why is this? It cannot be that gravity alone makes the lower branches droop for it acts on all alike. Look more closely and see if the disposition of all the branches of the beech tree is not such as to get its leaves to the light to the best advantage. During all our observations on trees we should test the following: The one main purpose of the stem of the tree, its trunk and its branches, is to get its leaves to the light.

Exercise: Every pupil should draw a beech tree as accurately as he can, but it should show the disposition of the branches above referred to. "A pencil is a good eye." Examine also a sunflower to see if it gets its leaves to the light in a similar manner; do the petioles of the lower leaves droop; and those of the middle leaves grow in a horizontal direction while those of the uppermost leaves rise?

Fig. 1.
A beech tree showing how its branches get their leaves to the light; the lower droop, the middle grow straight, and the upper rise.

LESSON II.

Adaptation to Light.

The Tree Grown in the Open Country and the Forest Tree.

Visit a walnut, oak, ash, or wild cherry tree that has grown in the open country and one that has grown in the forest.

Fig. 2.

This walnut tree grew in an open field; light called and its branches responded in all directions. It was photographed at the same distance as Figure 3.

How high is the tree in each case? How high is the first branch? It will be seen that in the open, every branch has responded to the influence of the light, has lived and has

Fig. 3.

This walnut tree grew in the woods; light was to be had from above only; its lowest, shaded limbs died; it is a tall tree.

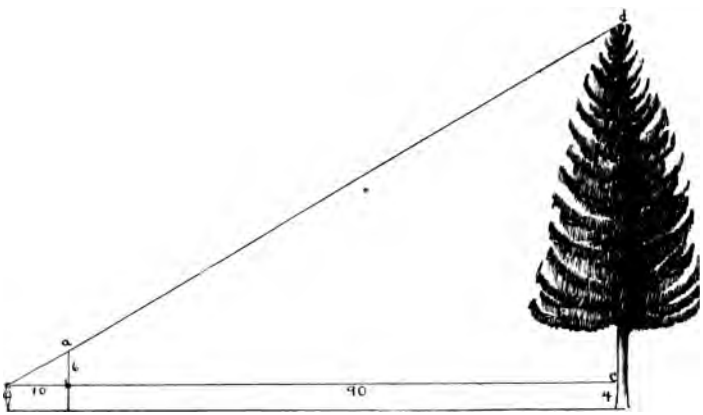
grown vigorously toward the light; horizontal branches are sometimes found as large as considerable trees in the forest. In the forest, neighboring trees have shut out the light and the lower branches have died; the highest branches, called upward still by the light, have grown and grown until the result is what we call the monarch of the forest. Fig. 2 is a walnut tree grown in a field; Fig. 3 is a walnut grown in the forest. These photographs were made at the same distance from the trees and correctly represent their dimensions. The circumference of Fig. 2 is 9¾ feet; that of Fig. 3 is 4¾ feet. So the country tree is much the older. The forest tree is, however, much taller and its lowest limb is much higher. In the pine forests of Europe, it is a business for some women, children and old men to cut off the under branches that have died in the shade and gather up others that have fallen and bind them in bundles for kindling purposes.

Exercise: Find and draw a tree that has grown alone in the country and one of the same kind grown in a forest, care being taken to draw them to a correct scale. Measure both trees just as they grow.

How to Measure a Growing Tree.

First, measure the height of your eye on the tree trunk, and mark the spot e. Walk back 100 feet from the tree to e and set up a pole between you and the tree so you can just see the top of the tree d over the top of the pole a. Mark the point on the pole b between your eye and the spot e. Now measure the distance ab; we will suppose it to be 6 feet. Measure the distance eb from your eye to b; we will suppose it to be 10 feet. Now the distance de is as many times ab as 100 feet is times eb. This is ten; therefore the tree is 10 times 6 = 60;

add to this the height of your eye, 4 feet, and you have 64 feet, the height of the tree. Or if you understand it—eb:ec::ab:dc. 10: 100::6: height of the tree above your eye.



LESSON III.

Adaptation to Light.

The Branching of a Fir-Tree.

Figure 4 is a fir-tree. You can tell a fir-tree from a spruce or hemlock by its leaves which have no petioles, but are attached to the branch by a slightly enlarged disk. Notice how perfectly conical its top is; the light makes it so. Go under the tree, close to the trunk and look up. You will see that the branches are bare except at their extremities. The leaves have all died where they were in shadow. Because the branches grow gradually shorter from below upward, the upper ones cannot shade the lower at their ends; here the leaves grow. When a tree has one main branch from root to top as this tree has, we call its branching *excurrent.* But it

is far less valuable for you to remember this than it is for you to understand that this is one way for every branch to get some of its leaves to the light.

Fig. 4.

A fir-tree; excurrent branching; every branch reaches a little farther than those above it and so all get the light.

Exercise: Find a fir-tree and sketch it to a correct scale; go back to the beech again and see if its branching is also excurrent. See if you can find a fir-tree, the branches of which droop like those of the beech.

LESSON IV.

Adaptation to Light.

The Branching of the Elm.

Figure 5 is an American elm in its winter condition. Notice that there is no main trunk above its lowest branches. Find the tree growing out by itself where every branch has an

Fig. 5.
The elm; deliquescent branching.

equal chance at the light. When a main trunk divides up into two or more somewhat equal branches and these branches

divide in somewhat the same way, we call this method of branching *deliquescent.* But the important thing for us to consider is whether every branch grows in the direction that will most quickly and certainly bring its leaves to the light. If the attraction of the light is the determining thing and there is a flood of it in all directions should we not expect a symmetrical top like this?

Exercise: Draw the elm showing its manner of branching. Find twenty different kinds of trees and determine for each of them whether the branching is most like the fir or the elm. Is the apple excurrent or deliquescent in its branching? The cedar?

LESSON V.

Adaptation to Light.

Unequal Lighting.

You are sure to see lack of symmetry in a tree, grown where one side is in light and one in shadow. Figure 6 shows a pitch-pine that has grown in a clump of evergreens. The main branch on the light side is 18 feet long. The longest branch on the other side is only 4 feet. A wild cherry tree growing between a linden and a sycamore near my home, is flat because it is shaded on two sides and not on the other two; its expanse from the light side to the light side is 40 feet while from the shady side to the shady side is only 20 feet.

Exercise: Find a tree somewhere so grown that it has little light on one side; it may be on the edge of a forest or on

the outside of a group of trees or near a building. Measure its expanse of branches and draw it to a scale. Find enough

Fig. 6.

The pitch-pine; the branches on the shady side are to those on the sunny side in length as 4:18.

such trees so that you will feel sure that the amount of light is one important thing in determining vigor and direction of growth.

LESSON VI.

Adaptation to Light.

Pendant Branchlets.

Notice Figure 64, Lesson XXXIX, and you will see that the circles of limbs are some distance apart; this leaves light spaces between them in which pendant branchlets have grown down and brought their leaves to the light. Find a Norway spruce and see that this is one of its characteristic habits of growth. You can tell a spruce from any tree that closely resembles it by the short, brown stems of its leaves. These pendant branchlets of the spruce give it a peculiar appearance in the distance. It should be one aim of our nature study work to name as many trees as we can by their figures at a distance of forty rods or so. The European larch has the same habit. It can be told from the tamarack, the tree that looks most like it, by its pendant branches.

LESSON VII.

Adaptation to Light.

Horizontal and Vertical Branches.

Figures 7, 8 and 9 show three branches of Norway spruce; 7 grew directly upright; 8 shows a side view, and 9 the view from below of horizontal branches. The vertical branch is round; the leaves grow on all sides of the branch; they grow in

Fig. 7. Fig. 8. Fig. 9.

Fig. 7. A round spruce branch; it grew upright and had light in all directions; Fig. 8 was horizontal and is flat; if turned through 90 degrees it would appear as wide as 7 or 9. Fig. 9 was horizontal and is seen from below.

like manner on all sides of the horizontal branch but the under leaves come around to the side in order to get to the light. The same lesson may be equally well learned from a hedge that is just ready to be trimmed; some of the long, fresh shoots will be found growing straight up, and, as there are eight rows of leaves on the stem it will appear round in full leaf, Figure 11; other branches will be found that have taken a horizontal direction and the leaves of these will have crowded together on the two sides and the branches will appear flat, Figure 10. Apple or peach branches will show the same thing, only there are but five vertical rows of leaves on these branches.

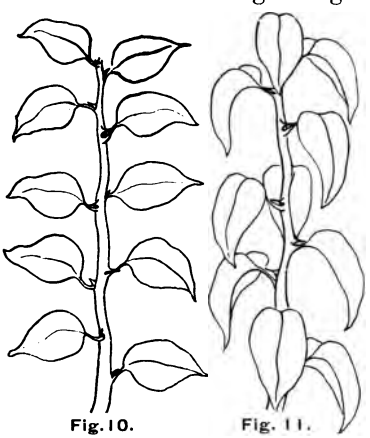


Fig. 10. Fig. 11.

Fig. 10, a hedge branch that grew horizontal. It is flat. Fig. 11, a hedge branch; it grew upright and round. Drawn from nature by Miss Helen M. Fiske.

If a two-ranked stem like beech, elm or hazelnut is studied it will be found that on a horizontal branch the leaves lie in the plane of the branch—look at right angles to it. On a vertical branch so grown that its light comes from above the leaves have turned ninety degrees on their stems and face the tip of the branch.

Examine and see if it is the petiole that brings the leaves into these varying positions.

Notice that the leaves of the spruce are short and narrow and that there are many vertical rows on the branches with the leaves close together; the hedge has broader and longer leaves with fewer rows and the leaves in its rows much farther apart. Does this ratio hold generally for leaves; the wider and longer the leaves the fewer the rows and the farther apart?

LESSON VIII.

Adaptation to Light.

The Behavior of the Petiole.

Examine a pumpkin-vine; it will be found that the petioles that come out on the upper side grow straight and spread their leaves out directly above; but petioles coming from the under side curve round and then grow out at the angle best suited to bring their blades to the light.

Examine a morning-glory or any other sort of twining vine; the petioles that leave the vine on the side next to the support all bend around so as to bring their blades to the light. Make the same study of a Virginia creeper growing on the side of a house. Is not the petiole of a leaf a contrivance to bring the blade to the light? Does it not grow straight or crooked, long or short, up or down or out, in order that it may do this? Pull a branch from the Lombardy poplar; its branches cling close to the tree,—grow almost straight up. Have the petioles all brought their blades around so as to face the light?

LESSON IX.

Adaptation to Light.

The Behavior of the Petiole. Maple Spray.

Fig. 12.
A maple spray, showing the longer petioles of lower leaves.

Figure 12 shows a maple spray. Study this figure with a maple spray before you. Study it at the tree; for the direction of growth, or the length of a petiole will often be determined by the shadow of leaves on a neighboring spray or on neighboring trees. Compare the maple spray with the beech spray, Lesson XV. Notice that on the maple branch there are four rows of leaves while on the beech branch there are but two. Notice again that beech leaves on the same spray cannot shade each other, that the maple leaves can and that they escape this calamity by the varying length of their petioles and their direction of growth. It must be some trouble and expense to a leaf to grow a long petiole, and if nothing is gained by it why should it do so? Do not pass from this lesson till you can see why the beech does not need long and short petioles, while the maple does. Study Lessons IX and XV together.

LESSON X.

Adaptation to Light.

The Aspen. The Prickly Lettuce.

The aspen, the Carolina poplar, the Balm of Gilead, the Lombardy poplar and a few other rare poplars have the petioles of their leaves flattened vertically so that the leaves quiver in the slightest breeze. Study this feature of the aspen tree if possible. Scott, in order to tell how perfect the calm, says,

"Scare the frail aspen seemed to quake."

This quaking permits the light to fall on leaves that otherwise would be in shadow.

The common prickly lettuce furnishes an interesting study; its leaves turn 90 degrees on their axes near the stem so that the leaf stands edgewise; they also turn so as to point in a general north and south direction from which it is often called the "compass plant." The effect of both these movements is to lessen the amount of light they receive. We must not get the notion that the more light the better for a plant, for plants can get too much light as well as too little; in tropical and semi-tropical countries plants have many ways of dodging or tempering the extreme light, see lesson LXXII and especially the cross-section of a purslane leaf, Figure 117.

LESSON XI.

ADAPTATION TO LIGHT.

The Shape of the Leaf-Blade.

Figure 15 is a leaf of a cut-leaved maple. Figure 12 shows leaves of the Norway maple. Go close up to the Norway maple and see it "as the squirrel sees it." Its branches are bare; now visit the cut-leaved tree; its branches are all cov-

Fig. 13. Fig. 14. Fig. 15.
Fig. 16. Fig. 17. Fig. 18.

Figs. 13 and 17. Notched, pinnately veined leaves of yellow chestnut-oak. Fig. 14. Round-lobed leaf of white oak. Fig. 15. Cut-leaved maple leaf. Fig. 16. Awned, lobed leaf of red-oak. Fig. 18. Pinnately compound leaf of clematis.

ered with small branchlets, bearing many leaves. Is not the reason for this that the sunlight sifts through between the leaf-lobes of the cut-leaved maple, while the broad leaf of the

Norway maple shades the main branches so that leaves cannot grow on their branchlets?

Exercise I: Estimate the number of leaves on a Norway maple and a cut-leaved maple of the same size. Have we not here on one tree a large number of leaves with small

Fig. 19. Fig. 20. Fig. 21. Fig. 22.

Fig. 19. Palmately compound leaf of horse-chestnut. Fig. 20. A chestnut leaf.
Fig. 21. The palmately lobed leaf of the sycamore-maple. Fig. 22. A mountain-ash, odd-pinnately compound.

working surface doing for one tree what a much smaller number of leaves with large blades do for another?

When the thermometer is 100 degrees in the shade, try the shade of these two trees. Try the shade of the locust, ash, walnut or Kentucky coffee tree in the same way; all of them have pinnately compound leaves somewhat like Figure 22. The light can filter through between the leaflets.

The pine has needle-shaped leaves; has it more leaves than the sycamore? Try to estimate the number of leaves on trees about the same size. Try also the shade of the pine. The light can sift through between its needles to leaves below.

Exercise II: Find young trees, five to fifteen feet high,

Fig. 23. Fig. 24. Fig. 25. Fig. 26. Fig. 27.

Fig. 23. Entire, heart-shaped leaf of lilac. Fig. 24. A greenbriar leaf showing stipules changed to tendrils. Fig. 25. A stipulate leaf of rose. Fig. 26. Oblique leaf of American elm. Fig. 27. Parallel-veined leaf of ginkgo.

growing in the shadow of a forest. Why have they larger leaves than similar undergrowth where the light is stronger? See if it is possible to make out a ratio between the size of the leaves and the intensity of the light; that is, that a larger leaf in a weaker light is required to do as much work as a smaller leaf in a stronger light.

Fig. 28.
The rosette leaf-arrangement. A mullein of the first year.

LESSON XII.

Adaptation to Light.

The Rosette Leaf-Arrangement.

Figure 28 shows a mullein at the close of the first season of growth. Such a mullein can be found in October. Three things are to be noticed; each leaf grows out between two of a lower circle; the upper leaves are smaller than those below them so they do not shade them much; the upper do not lie flat as the lower do and for this reason shade the lower less. How many leaves in the mullein, Figure 28, can get the light? How many in the mullein you are now studying and comparing with the cut? Draw accurately, as to direction of growth and size, the leaves of the mullein you have found. The mullein, thistle, cabbage and many other herbs are biennials; that is, they require two years to mature seeds. During the first season they store up the food which they will use the next in maturing the seed. A necessary part of the work of preparing the food stored in the root is done in the leaf, see Lessons XCII and XCIII. The October mullein is getting ready for the stalk and seeds of next year. Figure 54 shows the seed bearing mullein of the second year.

LESSON XIII.

Adaptation to Light.

The Stem's Main Duty.

The stem, (in the case of a tree, the trunk and branches,) holds the leaves up to the light; this main duty imposes upon it the additional duty of bringing nourishment and moisture up from the ground and of supporting the top against storms.

It may be noticed that trees grown in rich soil have much larger and taller trunks and branches than those grown in poor soil; oak forests in sand, as those at Oak Bluffs, Mass., are barely a third as high as those of our northern states. As one travels toward the north, trees become smaller and smaller until they at last trail beneath the snow. One notices the same thing in ascending a mountain; our prairie sunflowers in western Indiana and Illinois are fifteen feet high or more; as one goes west he sees them becoming lower

Fig. 29.
Birches on Mt. Katahdin. Photographed by Prof. J. F. Thompson.

and lower until at Denver they are three feet; as he ascends Clear Creek canon the same shortening goes on; ascending Gray's Peak one comes to brook plains carpeted from the melting snows on one side to the melting snows on the other with apparently stemless flowers, the prairie sunflower and its congeners from the plains. This seems to indicate that the stem is a great convenience under favorable conditions such as our rich soil affords, a necessity to be sure for large growth, but not for existence as roots, leaves and flowers are.

Varying conditions of soil and climate do not permit a plant to avail itself of the sunlight to the same measure, so the stem varies as its environment varies.

Exercise: Compare plants of the same species grown in different soils. When opportunity offers make the same observations while ascending a mountain.

Fig. 30.

Onions and corn growing in loam, clay, and sand to show influence of soil. From the Proceedings of the Indiana Academy of Science for 1902, by Prof. H. B. Dormer.

Figure 29 shows birches growing on top of Mt. Katahdin, Maine. They are not small because they are young, but because the climate compels them to be. The main stem has become a rootstock from which the dwarf branches grow.

Figure 30 shows on the left three onion plants, one grown in loam, one in clay and one in sand; on the right are three stalks of corn similarly grown. The effect of soil need hardly

be commented upon. The conditions of moisture, temperature and light were the same for all.

Exercise: Try raising potted plants in different soils. Try the effects of various fertilizers on plants. The secret of variations giving the fine greenhouse plants is due sometimes wholly to the fertilizer.

LESSON XIV.

Adaptation to Light.

The "Sleep" of Plants.

It will be shown, Lesson XCIII, that plants utilize sunshine in their work by day. Stems and branches hold their leaves up to the light and each petiole grows so as best to bring its blade into proper relations to it. Figure 31 shows an Abutilon photographed on a sunny day at noon. Figure 32 shows the same plant in the same situation at 10:45 p. m. Every leaf droops. The day expanse was 14 inches; the night expanse 9 inches.

Exercise: Grow squash, pumpkin, cucumber, etc., as potted plants and measure accurately the positions of their leaf-blades at midday and at midnight. The same measurements may be made on shrubs that grow in the yard. A good one to measure is redbud. Make also day and night examinations of bean and pea, growing in the garden. In the day time, every leaf is alert and adjusted to the light. Can it be that plants sleep and wake, work and rest?

What causes the leaves to assume these different positions?

We are accustomed to say that it is the stimulus of the light; but this Abutilon assumes the erect position before it becomes light. It begins to awaken about 4 a. m. and is fully

Fig. 31.
Abutilon, photographed at noon.

awake when it is light (January, 1903.) It wakens up in a dark room into which no ray of light comes, at its usual waking hour.

These night and day movements of plants are called nyctitropic; they may be studied to advantage in clover and Oxalis.

Fig. 32.
Abutilon, photographed at 10:30 p. m.

In Oxalis the leaves fall from the horizontal position until they rest against the stem; in clover on the contrary two of

the three rise and bring their upper faces together while the third leaf rises in such a manner as to cover the two somewhat.

Campbell says these movements are to diminish the radiating surface and prevent the loss of heat, but the Abutilon, clover and Oxalis all make these movements in a room that remains at the same temperature. Whether the action was at first caused by the alternation of light and darkness or by day and night changes of temperature or by both, the habit is so established that the movement is carried on for a time at least at a constant temperature and in total darkness.

Examine leaves also at midday on a very bright day and see if they respond to the stimuli and change their positions in the presence of too much light and heat as well as too little.

LESSON XV.

Adaptation to Light.

The Leaf-Arrangement of the Beech Tree.

An elm will do for this lesson as well. The leaf-arrangement and bud-arrangement, when no buds are suppressed, are the same for the same tree. The buds generally appear in the axils of the leaves, that is, just above the attachment of the leaves to the stem. It will be seen that the beech spray in full leaf is flat, that the leaves grow on opposite sides only; that there are two rows of leaves only on each branch; that consecutive leaves are 180 degrees apart; that if a string is passed around a beech branch from a leaf to those above it in order, the third leaf is over the first as shown in Figure 33. By this arrangement no leaf-blade can ever shade another on the same branch. For this reason they do not need long petioles to bring them to the light. Notice

that they do not have long petioles. Test this proposition on every plant you can find: the petiole of a leaf has for its main duty the task of bringing the blade to the requisite amount of light. Compare Lesson IX.

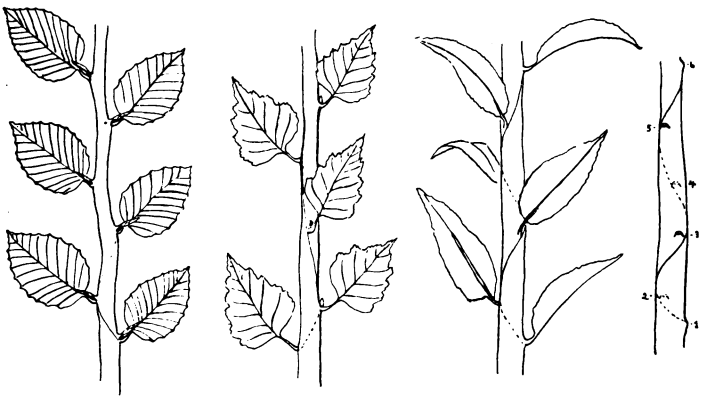


Fig. 33. Fig. 34. Fig. 35. Fig. 36.

Fig. 33. A two-ranked beech branch. **Fig. 34.** A three-ranked birch branch.
Fig. 35. A five-ranked apple branch. **Fig. 36.** A way to determine leaf-arrangement. Drawn by Miss Helen M. Fiske.

Exercise: Draw a beech or elm branch. The drawing should show for the purposes of this lesson that the petiole is very short and that the leaves are two-ranked.

LESSON XVI.

Adaptation to Light.

Leaf-Arrangement.

In previous lessons reference was made to the two-ranked leaves of beech, the eight-ranked leaves of hedge and the five-ranked leaves of apple. It was necessary to do this in order to study the light adaptations.

Exercise I. Get straight young branches of elm, beech,

mulberry, and hazelnut and compare them with Figure 33. This is the simplest of all leaf-arrangements. There are two leaves in one round; the leaves are 180 degrees apart and there are two vertical rows on the stem. Notice now that the arrangement of the branches is the same on those trees; notice that the bud-arrangement is the same; that buds and branches are alike just above leaves; this position of the

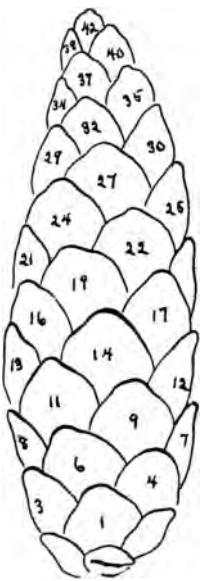


Fig. 37.

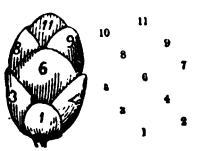


Fig. 38.

Fig. 37. A thirteen-ranked pine cone. After Gray.
Fig. 38. A five-ranked tamarack cone. After Gray.

branches can be seen more easily on some branching annual like the clematis or ragweed.

Leaves, then, have positions in which they grow; so have buds and branches; this has reduced the study of disguised leaf forms to a science instead of a notion. Position is the determining element. It is important for the student to learn this.

Exercise II. Get short, straight, young branches of birch and also some of the tall, rough, triangular sedge grasses; cut these off very close to the ground and examine the sheathing

Fig. 39.
A cabbage-palm—Melbourne, Fla.

leaves at the base. Compare their leaf-arrangement with Figure 34. Notice that there are three leaves in a round, that any two consecutive leaves are therefore one-third of 360 degrees, or 120 degrees apart. This will be much more diffi-

cult than exercise I. If you fail try exercises III, IV and V first and then return to II.

Exercise III. Get straight water sprouts of peach, cherry, plum and quince and cones of the larch and tamarack. Compare them with Figures 35, 36 and 38. Pass a string as shown in the cut. Notice that the sixth leaf is over the first; that the string to reach the sixth must pass twice around the stem. There are then five leaves in two rounds; or the consecutive leaves are 2-5 of 360 degrees, that is 144 degrees apart.

Exercise IV. Get similar branches of hedge, holly and plantain and compare them with Figure 11, and make calculations as before. How many rounds does the thread make before reaching the leaf directly over the first? How many leaves does it pass? What is the angular distance between consecutive leaves? How many vertical rows are there on the stem?

Exercise V. Get a cone of white pine and make out the arrangement in Figure 37 and make calculations as before. Answer the questions for the white pine given at the close of Exercise IV.

Notice that all these different leaf-arrangements are so many ways plants have to accomplish the one purpose of getting their leaves to the light. Figure 39 is a cabbage-palm. What has its trunk to do with getting its leaves to the light? The long petioles of the leaves? The arrangement of the leaves? The frayed out ends of the leaves?

LESSON XVII.

POLLINATION.

Self-Pollination.

Fig. 40.

A complete flower; three sepals, the smaller outer leaves; three petals, the longer inner leaves; six stamens and a pistil of three united carpels having three recurved stigmas. After Gray.

Figures 40 and 45 show flowers with sepals, petals, stamens and pistils. In Figure 40 the stigmas are recurved and at the center. Every one has seen the powder, often yellow, which the stamens bear. Figures 41 and 42 show photographs of some of this dust taken with a microscope; the figures show the grains many times as large as they really are. These grains of powder are called pollen. It has often been shown that plants will not bear seeds unless this pollen falls on the stigma of the pistil. This process is called pollination. Figure 41 shows a pollen-grain, the wall of which has opened and the contents of which are growing down through the top of the style toward the ovary. It does not cease to grow down until it reaches the egg-cell of the ovary when one of the pollen nuclei unites with the egg-cell and fertilization is complete. When the stamens that furnish the pollen grow in the same flower with the stigma on which they fall, we call the process self-pollination. When the stamens grow in one flower and the stigma on which their pollen falls grows in another flower, we call the process cross-pollination. Flowers which have both stamens and pistils are perfect flowers.

Exercise: Find a half dozen kinds of flowers that are per-

Fig. 41.

Two pollen-grains that have alighted on a stigma of purslane; their pollen-tubes are growing down toward the egg-cell in the ovary. From a slide by Mr. Vivian Floyd. x 300

fect. Count the stamens and stigmas in each so as to be sure the flower has both and sketch them, showing just the right number.

LESSON XVIII.

POLLINATION.

Staminate and Pistillate Flowers. A Monoecious Species.

If a flower contains stamens but no pistils we call it a staminate or sterile flower. There are many such flowers in

a single tassel of corn. If a flower contains pistils but no stamens we call it a pistillate or fertile flower. The silks that corn bears where the ear is to be, are parts of fertile flowers.

We name all those plants that we think sufficiently resem-

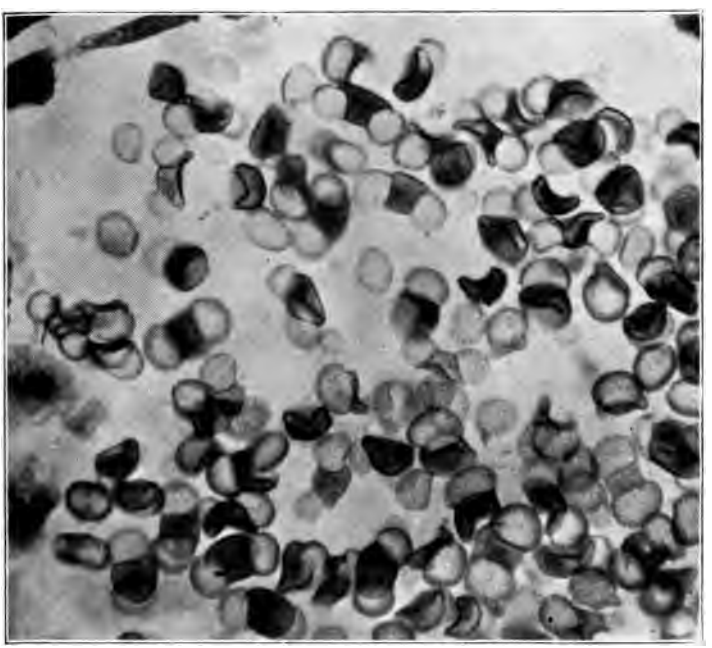


Fig. 42.

Pollen-grains of white pine with an air balloon at each end. x by about 400.

ble each other to have descended from a single seed or from common parents, a species. Corn, the marsh-marigold and the red maple are examples of species. When the staminate flowers grow on one part of a plant and the pistillate on another as in the case of corn, we call the species a monoecious species. When the stamens grow on one plant and the stig-

mas on which the pollen falls grow on another, we have cross-pollination, in which different individuals take part as well as different flowers. Yellow and white corn will, as is well known, mix across a road; this is because pollen from the tassels, the stamen bearing flowers of one kind, falls on the stigmas of the other kind. It is said that it will not do to plant watermelons and pumpkins in the same patch; the pollen from pumpkin blossoms will get on the stigmas of the watermelon blossoms and the melons will be ruined. Broom-corn and cane cannot, for similar reasons, be raised near each other. These are cases of cross-pollination between different species. Cross-pollination between individuals of the same species seems to result in stronger plants. Many experiments have been tried that show this; see Lesson XXVIII. We would be justified in concluding that it is so because nature has taken such pains to bring cross-pollination to pass.

LESSON XIX.

POLLINATION.

The Advantage which the Monoecious Species Has.

The tassels containing many staminate flowers, grow on the top of the corn stalk; the chances are that the pollen will be carried by the wind obliquely and that it will reach the pistil of some other stalk and so produce cross-pollination between flowers of two individuals. If the pollen grew in the same flower with the silks this would be far less probable. It may be said that the monoecious arrangement favors cross-pollination from plant to plant and is therefore a help. The ragweed furnishes another fine illustration of this. The sterile flowers grow in long racemes at the top of the weed. It is a habit some boys have to scrape up between their fin-

gers the yellow dust and its receptacles from the sterile flowers. Where do the fertile flowers and seeds of the ragweed grow? At least they grow somewhere lower on the weed than the sterile flowers do. The wind carries the pollen everywhere and doubtless effects cross-pollination from plant to plant generally.

LESSON XX.

POLLINATION.

The Dioecious Species.

It often happens, as in the case of the mulberry, that all of the trees do not bear seeds. This may be because one tree bears only pistillate flowers and the other only staminate flowers. The first kind is said to be a fertile, pistillate or female tree, the second a sterile, staminate or male tree. A pistillate tree will only bear when there is a staminate tree somewhere near enough to send pollen to its stigmas.

Exercise: Find a mulberry tree that bears and see how far it is to a pollen bearing tree. It would manifestly aid the wind in bearing the pollen long distances if the pollen-grains were winged. This is often the case. Figure 42 shows the winged pollen-grains of white pine.

Herodotus makes note of the fact that the Egyptians had a yearly festival, in which they went to the desert and brought sterile palm branches and waved them over the fertile trees they had planted along the Nile. By this means they could give all their space to the growing of trees that would bear. It would be interesting to know how they came by the knowledge that such action would cause fruit to grow, long before we knew the office of pollen in fruit production.

Exercise: See if box-elder is a dioecious species. Is red

cedar? Is Ailanthus? Is the persimmon? Is any willow you know?

The plain advantage of the dioecious arrangement is that cross-pollination is the only kind that can occur; but it seems to be a law that every advantage has its accompanying disadvantage; the disadvantage in this case is that only part of the trees can bear fruit.

LESSON XXI.

POLLINATION.

Flowers in which the Pistil Appears First.

Common plantain is a weed every one knows; it has a rosette of tough broad leaves from which it sends up a long spike of flowers. This spike blooms from the bottom up. In any given flower the pistils ripen before the stamens do; it is therefore entirely impossible that any stigma should receive pollen from a stamen in the same flower. Protogyny is the term we use to describe this arrangement; the word means pistils blooming first. This is one of many ways by which nature provides for cross-pollination. If the lowest flowers on any stalk are fertilized at all it must be with pollen from another plant; it is often doubtless true that higher stigmas receive pollen from other plants. That the ripe pistils are above the ripe stamens favors this. The growth of the plants in societies also favors it.

Some species of plantain may be found blooming all summer long. Sketch a spike when the ascending circle of protruding stigmas has reached the middle of the stalk with the circle of stamens below it.

LESSON XXII.

POLLINATION.

Flowers in which the Anthers Appear First.

The fireweed, Epilobium, is not so common as the plantain. I have, however, seen it blooming in many parts of the country, late in August. Its time for blooming is given from July to September. It has a pink-shaped blossom with a reddish-purple color. It is some four feet high and very striking. Its anthers come out first, the stigma being bent quite out of the way, and discharge their pollen and wither; the pistil now becomes erect; the anthers of its own blossom having withered, only cross-pollination can occur; bees carry pollen from one flower to another and thus produce cross-pollination. Fig. 43, after Gray, shows the ripe stamens and the recurved, unripe stigma. Figure 44, also after Gray, shows the erect ripe stigma and withered stamens.

Fig. 43.

Fig. 44.

Fig. 43. Fireweed blossom; stigma green and recurved, stamens ripe. Fig. 44. Fireweed; stigma ripe and erect; stamens withered. After Gray.

Figure 45 shows two blossoms of Amaryllis. The one on the right has ripe stigmas and withered stamens; the one on the left unripe, recurved stigmas and ripe stamens. Notice the white stigma quite below the anthers in front of a petal. Notice that it is not divided. Nine days later when its own stamens were wholly withered it had bent up to about their position so that an entering insect would brush it and its three stigmas were fully ripe and unfolded. The stamens being now mature in the left blossom are in a position to be brushed by an entering insect.

Fig. 45.

Two blossoms of Amaryllis; the stamens and pistils show the same thing as Figures 43 and 44.

LESSON XXIII.

POLLINATION.

Flowers and Insects. Bees.

A fine beginning of the study of this relationship can be had by the careful study of the parts of a bean blossom; after which the visits of the bees to the blossoms must be watched. The wings of the bean blossom (1) Figure 46, furnish a landing place for the bee; it must land here in order to get the honey. The style, stigma and stamens are enclosed in the keel. The stamens early shed their pollen which lodges on the hairy style near the stigma, Figure 47. The weight of the bee on the wings presses the style and stigma out in such a manner that the stigma picks up pollen from the bee's body that came from another flower and at the same time the style scatters down on the bee its pollen to be carried to the stigma of the flower next visited.

Fig. 46.

Fig. 47.

Fig. 46. A bean blossom; 1, the wings on which the bee lights. 2, the keel in which are the stamens and pistil. After Gray. Fig. 47. Bean blossom. The weight of the bee on the wings causes the stigma 1, and the hairy, pollen-laden style 2, to come out of the keel. The stigma strikes the bee and picks up pollen from another flower. The blow makes its own pollen fall from the style on the bee for the next flower he visits. After Gray.

Exercise: Press down on the wings of the bean blossom where the bee must light and watch the naked stigma and pollen-laden style come out. Cipher out the entire machinery and watch the bee's visit.

GLEICH UND GLEICH.

"Ein Blumenglökchen	A tiny hare bell
Vom Boden hervor,	In the meadow grew up
War früh gesprosset	And hung out enchanting
In lieblichem Flor;	Its little, blue cup;
Dan kam ein Bienchen	A bee came and sipped
Und naschte fein: -	Of its sweets daintily;
Die müssen wohl beide	They must for each other
Für einander sein."	Be flower and bee.

Goethe.

LESSON XXIV.

POLLINATION.

Flowers and Insects. Butterflies and Moths.

Adaptations between flowers and insects to produce cross-pollination are very numerous and common. Some of them

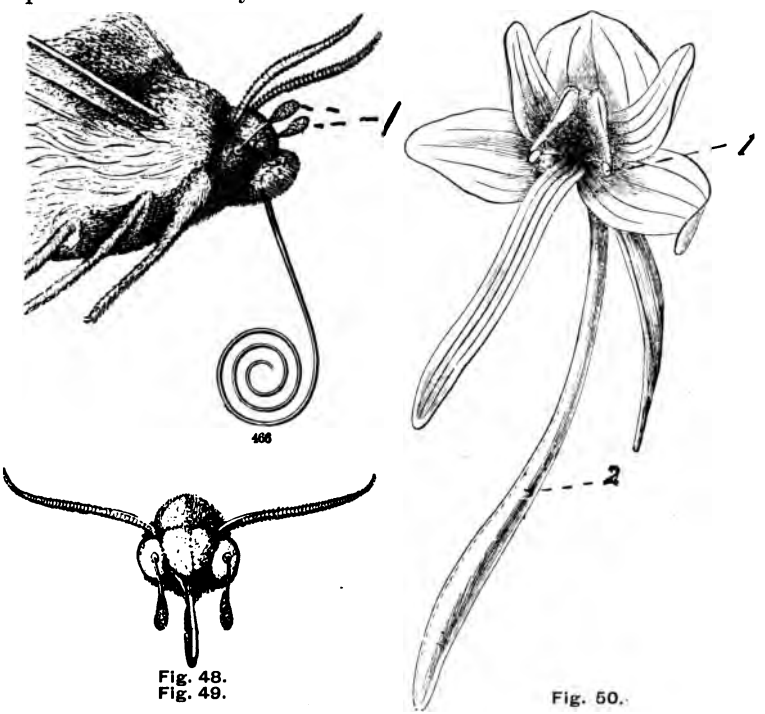


Fig. 48.
Fig. 49.

Fig. 50.

Fig. 48. Head of a moth. Its long tongue enables it to reach the nectary of an orchid shown in 2, Figure 50. Pollen masses 1, of Figure 50, adhere to the moth's eye by the disk; they are thus carried to the flowers subsequently visited. Fig. 49, the pollen masses by their gravity, turn down so as to reach the stigmas of flowers later visited. After Gray.

Fig. 50. An orchid blossom, after Gray. Its pollen mass adheres to the moth's eye by a glutinous disk, 1, while the moth is getting nectar.

are very complex and interesting as for instance the lady's-slipper, which will only let a bee out of the "slipper" along a road that forces it to rub first against the stigma and pollin-

ate it and then against the stamens and gather pollen for the next flower. The relations between certain other orchids and moths are as remarkable.

Figure 50 shows one of the orchids. The nectar is at the bottom of the long spur 2. The moth's tongue is just the instrument to reach it there. The opening into the nectary is so small that ants cannot enter; this is the case with many flowers; ants have no wings; they cannot fly from flower to flower and carry pollen for cross-pollination; it is therefore as necessary to keep ants out in some way as it is to attract bees, butterflies and moths.

Notice the flower again; at 1 there is a glutinous disk that carries many pollen-grains on a long stalk. These two disks are so situated that when the moth is taking nectar they will touch and adhere to its eyes as shown in Figure 48. Gravity then pulls them around to the position shown in Figure 49. When the moth visits succeeding flowers these will be thrust down to the concealed stigmas and cross-pollination will take place. Coordination is common between the various parts of one animal or plant, as for instance the tiger's claws and teeth go with the savage disposition; but here moth and flower fit each other like the nose and the spectacles. How came this fitness to pass? The way to study this question is to notice from year to year carefully all similar relationships and see if they do not finally fall into a system.

LESSON XXV.

POLLINATION.

Symbiosis.—"Reciprocity."

Bees get pollen and nectar for the hive from the flowers. Flowers get the inestimable advantages of cross-pollination from the bees. The relationship is one of mutual helpfulness. Symbiosis means life together. Butterflies and moths get nec-

tar and pay for it with service in cross-pollination. The world of life is full of instances like this. The raspberry and cherry feed the bird and the bird plants their seeds in distant soils. The kingfisher digs the hole in the bank and the bumble-bee has been known to occupy it with him and keep the small boys and other enemies away. The rattlesnake and the

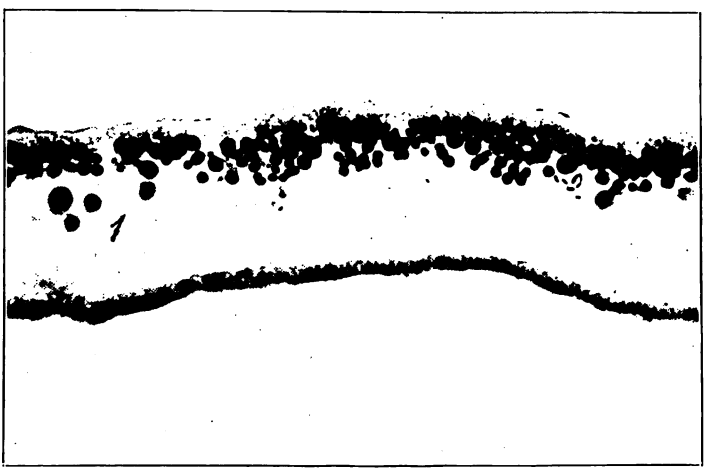


Fig. 51.

A cross-section of lichen, showing its compact upper and lower layers to prevent drying out; its inner reservoirs for moisture, 1, and the symbiont within 2, the round, black cells. Their real color is green.

prairie-dog sometimes live together for similar reasons. The lichen has imprisoned a green plant between its leathery exteriors. The lichen holds the green plant up to the light, gives it support and protects it from the drought on rock or tree, while the green plant gathers food for both.

Exercise: Cut a lichen in two with a sharp knife or razor and notice the green strip between the two white ones. Figure 51 is a photograph of a cross-section of a lichen and its imprisoned alga. The alga has been taken from the lichen

and reared separately; so it is an independent plant. What is the relationship between man and the domestic animals and plants? That is, are man and corn mutually helpful? Are men and horses?

LESSON XXVI.

POLLINATION.

Flowers and Insects. How the Ants Are Kept Out.

Fig. 52.

Cyclamen blossoms. The flower nods and the floral envelopes turn back up in such a manner that the entrance of ants or rain into the blossom is impossible. The lines in the petals shown in the blossom to the right were caused by eosin absorption.

One common way is given in Lesson XXIV. There are several other ways; the plant is sometimes surrounded by a water cup,—the teazel is an example. It sometimes is covered with bristly, downward pointing hairs in some part; sometimes these hairs are sticky and impede or even catch the ant; sometimes the plants are slick and the ant, in her efforts to stick on, pierces the skin of the plant and a viscid juice turns her back or catches her; sometimes the flowers are nodding and she can't crawl down to the edge of the corolla or calyx limb and safely turn and crawl back up to the nectar; sometimes the nectar is shut in and the door will not open except to the knock of the friendly bee.

Exercise: Be on the watch for all these methods of arresting the ant. See if you can find a smartweed that grows both on land and in water, having a water cup to keep ants away when it grows out of the water, which it leaves off when it grows in water. Read chapter III of Sir John Lubbock's "Ants, Bees and Wasps."

LESSON XXVII.

POLLINATION.

Flowers That Never Open.

Pollination sometimes occurs in a closed flower. This must always be self-pollination. The anthers that furnish the pollen and the stigma on which it lodges must belong to the same flower.

Fig. 53.
A violet plant dug in December. Large pods of cleistogamic flowers, 2, and pods of other ordinary flowers opened, 1.

Exercise: In the spring, examine every sort of violet that you can find, especially those that seem to have no stems; you will find a second kind of blossom concealed by the leaves, hard to find, but which bears nevertheless, more seeds than the flowers you have always known, Figure 53. These blossoms never open. There are flowers belonging to sixty different genera that are self-pollinated without opening. Cleistogamy is the name given to self-pollination in closed flowers.

Some of the advantages of

cleistogamy are: 1. Pollination is sure to occur. 2. It is not necessary for the flower to provide so much pollen. A cleistogamic flower grows some 400 grains of pollen; flowers which depend on insects to carry their pollen produce many times 400 and other kinds of plants yet to be described, see Lesson XXX, so many that the number can be estimated, not understood. Here, as elsewhere, advantage and disadvantage are balanced. The cleistogamic plants are weak. It is believed that they lack a factor that is necessary to their highest development. For some unknown reason, copulating cells from individuals of a species diverse in their origin give a strength and variety not otherwise to be had. Many simple plants and animals reproduce by division of the parent; but these do not improve; they live on and on at one dead level. Some eggs will grow into new individuals without fertilization; we call the process parthenogenesis; but the parthenogenetic species does not improve from generation to generation. A capital exercise for any one provided with a microscope would be, to estimate the number of pollen-grains in a cleistogamic flower of violet, an anemophilous flower like pine and an entomophilous flower like clover.

LESSON XXVIII.

POLLINATION.

Results of Experiments in Cross and Self-Pollinated Plants of the Same Species.

Darwin raised 73 morning-glory plants from seeds produced by cross-pollination and in the very same soil 73 plants from seeds produced by self-pollination; these sets of 73 plants both belonged to ten generations. The height of the first 73 was to the height of the second 73 as 100 to 77. So the crossing made stronger plants.

His crossed and not crossed plants of the ninth generation bore seed by weight as 100 to 61. These experiments confirm what we should expect from the fact that nature takes such pains to produce crosses and the further fact that crossing actually takes place among all higher plants.

Exercise: Cut the tassels from a few hills of corn before it ripens so that you can be sure cross-pollination from plant to plant, must occur. Dust the pollen from its own tassel on the silks of a few other stalks in the same row growing close by and see which makes the best corn.

LESSON XXIX.

POLLINATION.

Why Flowers Are Showy. Entomophilous Plants.

The word entomophilous means insect-loving. It is applied to all those plants that depend on insects to carry their pollen. Such plants have bright colored flowers. Examples are red clover, white clover, morning-glory, hollyhock, snapdragon, Catalpa, etc., all showy flowered plants, all plants the flowers of which attract general attention. It is believed that they are showy in order that the insects may see them. Why should they provide pollen and nectar for the insects and then not inform the insects in some way where they are? The odor of the flower serves the same purpose; a single flower might grow where the bee could not see it; in this case the odor alone tells the tale. We learned in Lesson XXVII that flowers that never open are inconspicuous. They are so inconspicuous that although they grow on our well known and universally loved violets, very few people indeed ever saw them. No doubt it is greatly to the advantage of flowers, that do not depend on insects to help them, to be inconspicuous.

Exercise. Keep a list all summer long of the plants you see visited by insects. See if you can find out how it is necessary for the insect to become covered with the pollen and, also, to brush it on the stigmas of the flowers they afterward visit.

LESSON XXX.

POLLINATION.

Why Trees Have Not Showy Flowers. Anemophilous Plants.

The word anemophilous means wind-loving. It is applied to all those plants that depend on the wind to carry their pollen. This includes most of the forest trees north of the Ohio river. Most people do not know that our beeches, oaks, hickories and pines, etc., ever bloom at all, but if we examine them in the spring we shall find that they produce countless millions of pollen-grains; enough, so that a single tree can give them to the wind and fill all the air for long distances. The trees are tall; they can take advantage of the wind as low herbs cannot. It is a considerable tax on a plant to produce large, showy blossoms. Why should they do this when they have a perfectly adequate way to get all done that insects could do?

Exercise: Make a list of anemophilous plants. You may at first write in this list all plants with inconspicuous flowers; then notice to see whether bees visit them and if they do, note this fact. You cannot learn too soon that all our distinctions and dividing lines are artificial and for our convenience. You can not help observing, if you look, that many plants are crossed both by wind and insects and that self-pollination often occurs by the agency of both insects and wind and also

in the very same plants without the agency of either of them. Let apparent inconsistencies be an incentive to you to look again. Sooner or later you will find that the sum total of the influence of wind and insect is to produce cross-pollination.

LESSON XXXI.

ADAPTATION TO CLIMATE.

Storms.

Stand by the window and watch a tree when the fiercest storm is on; see how trunk and branches and leaves, if there are any, yield to the storm. Where is the strain greatest? Is it not just at the ground? And yet is not this just the place where a sound tree never breaks? Did you ever try to split a stump? When the sound tree must fall does it not always break a few feet above ground or else blow up by the roots? How does it come that the strongest place in a tree is the place of greatest strain and danger? Watch a very small tree, only two or three years old, in a storm. Does it not yield to the strain, even to the extent of bending over to the earth sometimes? Would this not have a tendency to twist the grain at the ground and make the grown tree stronger there? The storm then strengthens most where it threatens most.

Try to split a tree that has grown for a long time on the edge of a forest on the windward side and another that has grown in the middle of the forest; which splits the more easily? Why?

In parts of Europe, large areas are planted in trees. Hills and mountains are kept covered in this way by forests. As one ascends the Brocken he sees every few hundred feet, a

small, fenced area. Trees are being sprouted in these to be planted out subsequently at the same altitude. They are raised from the start, subject to the same tempests, rains and temperature that will surround them when they are trees, and in the same kind of soil.

LESSON XXXII.

ADAPTATION TO CLIMATE.

Annual Herbs.

In the northern United States, the growing season is practically between March and November. During the winter the temperature may fall to 20 degrees or more below zero. Most indigenous plants have habits which specially adapt them to this. Consider a tender herb like the ragweed; as winter approaches, it must cover itself with a clothing that can resist this cold and the accompanying wet, or die. I presume most of us think it dies, but that is not quite the case. It selects a small part of itself which we call the seed, to which it gives a covering adequate to withstand all the exigencies of winter and keep the embryo within alive. To have protected its entire body or even the main part of it would have been very expensive and, although some plants do this, if all plants did it we would have to have far fewer plants for there would not be room for them in the world.

One way then to meet the conditions of winter is to reduce life to the compass of the embryo and wrap it up securely with the food necessary to start it in the spring.

The beans we eat, the corn, the wheat, contain an embryo in every grain. Every one of them is a plant reduced to its winter condition.

Exercise: Make a list of fifty plants that live through the

winter in their seeds only. In making this list, you must know from careful examination that the root as well as the top, dies. While this is true of the mullein or thistle that bears seed, it is not true of all mulleins or thistles.

LESSON XXXIII.

ADAPTATION TO CLIMATE.

Biennial Herbs.

A biennial plant is a plant that lives for two years only; that requires two years to bear seed. The root in all cases survives the first winter and the seed the second. The thistle mullein, dandelion, turnip and cabbage are examples. The mullein does not grow a long stem the first year. This is an adaptation to the winter it must pass. It grows flat on the ground, Figure 28, and has a thick covering of branched hairs. These may serve to temper the light of the sun; to hold dampness away from the surface of the leaf so that when it freezes it makes a cloak to keep the leaf warmer than it would be if naked, to check transpiration, or to protect the mullein from enemies that would otherwise eat it. The chief adaptations of the wild biennials like the mullein and thistle, to climate are that they grow only a short stem the first year, and they shrink to the dimensions of seeds the second.

Exercise: Make a list of biennial herbs. Watch marked plants and see that they die when they seed at the end of the second year. Figure 54 shows a two-year-old mullein at seeding time. Compare it with Figure 28.

Fig. 54.

A two-year-old seed-bearing mullein. Photographed by Prof. J. F. Thompson.

LESSON XXXIV.

ADAPTATION TO CLIMATE.

Perennial Herbs. Solomon's-Seal.

You must know this interesting plant if you do not. Figure 55 shows the underground stem with its peculiar seals, the places where the plant grew in previous years, and a terminal bud. The seals mark the place from which the aerial stem

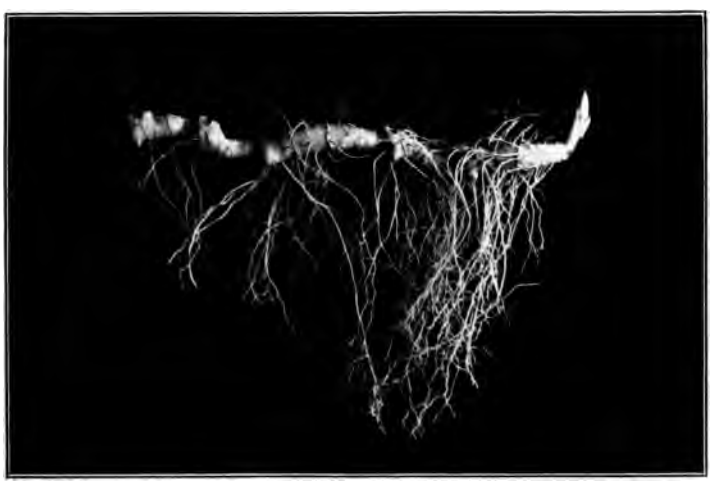


Fig. 55.

Underground stem of Solomon's-seal. The scars or "seals" are shown above where the above-ground stem grew one, two, three and four years ago.

broke off last year and for the three years before. The root-stock is dying at the left. Its adaptation to winter manifestly is that it dies down to the ground at its approach and lives only in its underground stem and its seeds.

Exercise: Make as long a list as you can of plants in your vicinity that live through the winter by dying down to the

ground only; it may help a little to ask, do ferns do this? Does bloodroot do it? Does blue-grass?

LESSON XXXV.

ADAPTATION TO CLIMATE.

Deciduous Forests.

The falling of the leaves in autumn is one of nature's great phenomena. To one born in the tropics, where verdure is per-

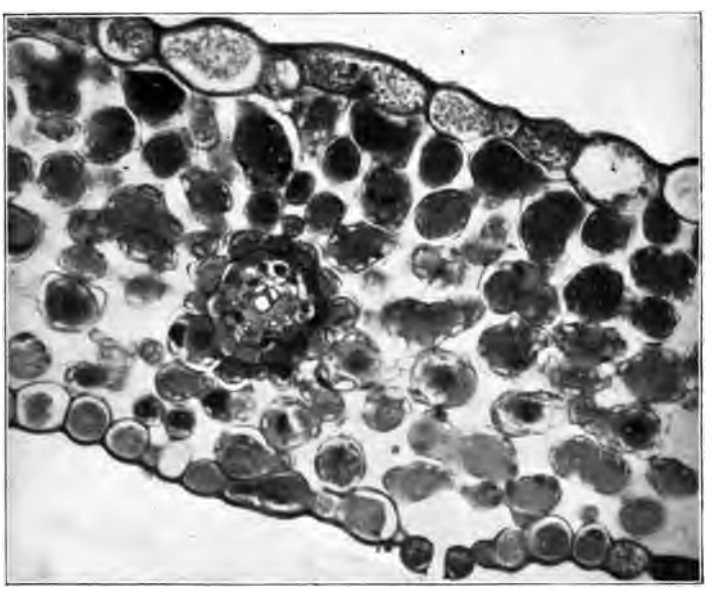


Fig. 56.

A cross-section of a deciduous leaf, a fern leaf; a stoma is shown open below. All the cells between the two layers of epidermis are working cells as their chlorophyll granules show. x by about 200.

ennial, nothing is more striking. We are used to it and the strange thing for us would be for them not to fall. The fall-

ing of the leaves is a preparation for, an adaptation to winter.

Two choices are open to a tree: one is to so cloak its leaf surface that it can resist the cold of winter; the other is to shed its leaves. Each plan has its advantages and disadvantages; each has been followed by successful species. The sycamore saves itself the trouble and expense of protecting its leaves by shedding them; but when spring comes, it must spend many days of its precious time in getting its leaves back again ready for work. Figure 56 is a cross-section of a leaf that perishes as winter approaches; notice how thin is the outside protecting envelope. One of the stomata for admitting air is shown, open below. All the cells between the upper and lower layer are working cells. They are supplied with sap by means of the leaf's veins, one of which is shown near the middle of the section.

Exercise: Collect a half dozen different kinds of evergreen and as many deciduous leaves and see which will tear the easier.

LESSON XXXVI.

ADAPTATION TO CLIMATE.

Evergreen Leaves.

The pine has taken the second plan, mentioned in the last lesson: it protects its working cells. Notice again, how tough its leaves are. Find out anew that its outside covering is tougher than that of the leaves of deciduous trees. Figure 57 is a cross-section of the half of a leaf of the Scotch pine. You can tell this tree because it has reddish branches; it has leaves about three inches long and two in a bundle. Its leaves are covered with a white powdery substance and have a grayish green appearance. Notice how thick are the walls of the

outside row of cells and also of the cells next to it except in the places where the leaf mouths for the admission of air are. Notice that this second layer is three cells thick at the corners. It would be difficult to find anything more remarkable in its adaptations, its fitness, than the pine leaf is. The cells from

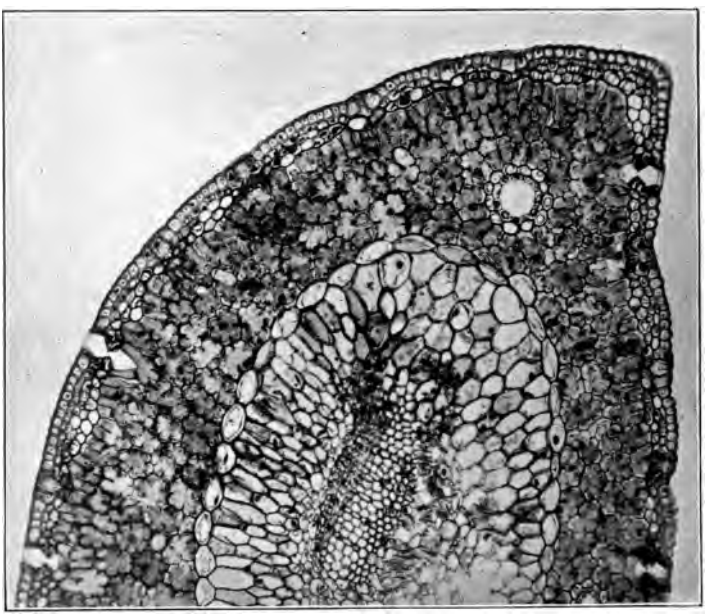


Fig. 57.

A cross-section of pine leaf. It shows from without in, 1, a thick walled epidermis; 2, a thick walled hypodermis, both pierced by the stomata; 3, chlorophyll-bearing cells, to be known by their infolded walls. They contain a resin duct, near the corner; a chain of bundle-sheath cells, 5, surrounding a fibro-vascular bundle. x by about 100.

the protecting outside layers to the large empty row, the bundle-sheath, are working cells; they contain the green of the leaf, called chlorophyll. These green granules require surface positions on the cell wall in order to work. The cells *have* their walls infolded to increase the surface to which the

chlorophyll granules may cling. These cells of the pine are packed very close together in pavements one above another throughout the length of the leaf, with a slight space between

Fig. 58.
An evergreen forest.

for air, in order to save space, so precious because it must be protected, at such cost to the tree. Figure 58 shows an evergreen forest. It and Figure 3 are December pictures; the one a Florida and the other an Indiana landscape.

LESSON XXXVII.

ADAPTATION TO CLIMATE.

Buds.

It seems to us that buds, as we see them in winter, are necessary to trees; that they are to be expected; a matter of

course; so they are in our climate; the tender, growing points of a tree must be protected against the rigors of winter. There is no reason for such buds, and there are none, where there is little or no change of climate.

Fig. 59. Fig. 60. Fig. 61. Fig. 62. Fig. 63.

Fig. 59. Apple buds, five-ranked. Fig. 60. Large, well protected hickory buds. Fig. 61. Lilac buds; scales opposite; this is well shown in 61 a. Fig. 62. Buckeye buds. Fig. 63. Beech buds.

Exercise: Gather some large buds from hickory, buckeye or horse-chestnut; count the scales that protect the living parts. Are there hairs in the bud to add to the warmth? Is there a varnish or any other means to prevent the bud from

getting wet? Gather walnut, beech, lilac and maple buds. What difference is there in the arrangement on the stem? Is it the same as the leaf-arrangement? Where are the buds of sycamore? Locust? Is there any tree in your vicinity that conceals its buds under the bark? Consult the accompanying Figures, 59 to 63.

An interesting phenomenon one may occasionally see is due to latent buds. The early buds of willows are sometimes killed in spring by frost; the trees have the power to produce branches in this case by means of the latent buds; but considerable time is required to bring them on; so the willow's second spring dress comes later than the leafing out of the forest trees. It is as if it had resolved not to be caught the second time.

During the winter of 1900-1901, most of the sycamore buds were killed by the severe cold; in the spring the few buds that had escaped leafed out and after two weeks or more latent buds were developed on the other branches and the two sets of leaves of different sizes could be distinguished until midsummer.

LESSON XXXVIII.

ADAPTATION TO CLIMATE.

The Persimmon Tree. A Special Case.

Examine carefully several branches on which persimmons grow and you will find that they grow on branchlets that have grown the same year. This is greatly to their advantage during winter. Fruit can hardly be killed when it does not exist. The winter might be so cold as to kill the tree; but if it is not, the branches of the year will grow out and put out flower buds and flowers and bear fruit. This is a great advantage and would leave the persimmon quite ahead in the struggle with frost, only it must take also its disadvantage, which is that a

much longer time is necessary in which to mature its fruit, and so it may be caught by the frost.

LESSON XXXIX.

ADAPTATION TO CLIMATE.

Influence of the Wind.

Figure 64 shows a Norway spruce. It grew in an open space where light could be had in all directions. It should

Fig. 64.
Norway spruce; branches longest on the leeward side.

have been as symmetrical as the fir in Figure 4 is. Notice that the branches are longer on the right hand side. This was the

northeast side of the tree. To the southwest there is an open space of several miles; prevailing southwest winds have thrown the symmetrical light influence out of balance. They have lessened growth on the southwest side and increased it on the northeast side. In many countries the winds are stronger and they blow much more steadily than with us; in

Fig. 65.

A live-oak forest leaning from the seaward, windward side. Melbourne, Fla. View from the south.

such places exposed trees lean and stretch their long limbs in the direction the wind blows in a very striking manner. Figure 65 shows a live-oak forest near Melbourne, Florida, every tree of which leans very strongly from the ocean, the direction from which the prevailing winds come. Figure 66 shows a single oak from the same forest photographed from the other side. Neighboring trees made it impossible to get the entire tree in the picture. That it leans from something is, however, evident.

Exercise: Find twenty-five exposed trees and see if you can determine by a study of them that the prevailing winds have

Fig. 66.

A single oak of the forest shown in Figure 65. View from the north.

modified their growth; look in places between forests that act somewhat funnel-like in directing the wind.

LESSON XL.

THE LEAF.

The Foliage Leaf.

The most conspicuous thing in the plant world is the green leaf,—the foliage leaf, as we call it. A complete foliage leaf

has a blade, a petiole, and stipules. Figure 31 shows all these parts; Figures 24 and 25 show the stipules. When there is more than one blade, we call the branched leaf compound, Figures 19 and 25. When these are arranged as in Figures 22 and 25 we call the leaf pinnately compound. When they are arranged as in Figure 19 we call it palmately compound. Figures 20 and 21 show leaves pinnately and palmately veined.

Foliage leaves have many different forms: Figures 12 to 27 show a few of them. It is important for us to consider in the presence of every tree, every plant, how its leaves, considering form, size, number and arrangement have successfully solved the problem of getting to the light. We must learn to consider green leaves as light traps; they cannot discharge their most important duty, photosynthesis, without the light. If we cannot understand this duty now, we need not be too much disturbed; no one fully understands it. See Lessons XCII and XCIII. It is enough for our purposes now to know that no tree can live without, at some time of the year, an expanse of green, which in our latitude, the leaves furnish.

Exercise: Learn to tell trees by their leaves. Begin with the commonest tree in your neighborhood. Collect, press, catalogue and draw accurately its leaves. Question yourself about the leaf's apex, its base, its margin, its lobes, if it has any, and its leaflets, if it is compound. Is its surface rough? Try the slippery-elm. Is it hairy? Try the white poplar. Is it smooth? Is it shining? Is the color the same above and below? Try the silver maple. Is it petiolate? Has it stipules? Is it thick or thin for a leaf? Tough or tender? What comparative advantage or disadvantage has the tree from every quality of its leaves?

LESSON XLI.

THE LEAF.

One Duty of Green Leaves.

Fig. 67.
Leaves giving off moisture. Transpiration.

Figure 67 shows a fresh, green growing end of a plant which was cut off obliquely and smoothly from its stem and thrust through a card board into a tumbler of water and covered with a second dry tumbler. The leaves have given off water which has collected in droplets in the upper tumbler. This action of the leaf is called transpiration.

Exercise: Prepare an apparatus like this and after some two days try to form an estimate of the amount of moisture given off by all the green leaves of the great forest, or grass covered plain. You must not think any one can do this accurately with data such as this experiment alone furnishes, but it is interesting to consider to how great a thing our experiment points. The air cannot for many reasons be so dry where forests are as it would be without them. We must of course, notice that the conditions of our experiment are not those of a growing plant. Our cutting absorbs from water, not from the soil, with its varying degrees of moisture; it absorbs through its cut end, not through roots. The air in the

tumbler where the moisture is given off soon becomes saturated with moisture, which the air surrounding forests and plains rarely is. What our experiment shows is the fact of transpiration.

LESSON XLII.

THE LEAF.

Leaves in the Role of Spines.

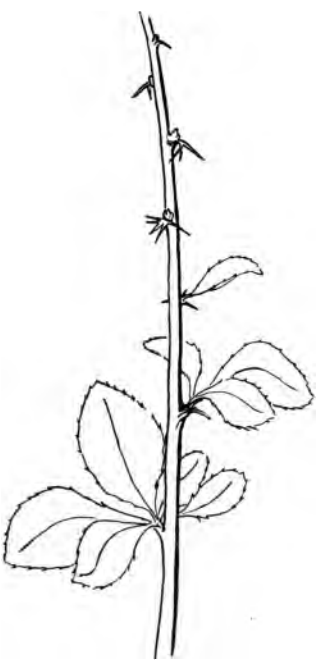


Fig. 68.
A barberry spray; leaves become thorns.

Leaves sometimes become spines; we know this because we find the spines in the position of leaves or of stipules. We know it also because we find all degrees of transition from leaves to spines. The leaf of the thistle is armed with spines. The barberry bush shows all stages in the transition from leaf to spine, Figure 68. The locust has a pair of spines at the base of its leaf in the place of stipules. The prickly ash shows a similar modification. The English holly has spines on its lower leaves; these continue as high up as a cow can reach; above this it has no spines. Southey writes of this tree:

"Below, a circling fence, its leaves are seen
Wrinkled and keen,
No grazing cattle through their prickly round
Can reach to wound:
But as they grow where nothing is to fear,
Smooth and unarm'd the pointless leaves appear."

Spines become gradually larger until we at last begin to call them thorns; but size does not determine; spines do not become thorns; thorns are modified branches. In the same way we determine the nature of tendrils, Lesson LI, we can tell whether we have thorns or spines in a given case. Do they come off with the bark and have they the position of leaves? Then they are leaves. The position of a branch or a permanent union with the wood declares them thorns.

Exercise: Examine haws of all sorts, the honey-locust, the prickly ash, and determine whether their sharp appendages are in the positions of leaves or branches; whether they come off with the bark or are a part of the wood of the plant.

Prickles such as one finds on raspberries must not be confounded with leaf-spines. They are emergencies in the nature of highly complex and hardened hairs.

LESSON XLIII.

THE LEAF.

Leaves in the Role of Bracts.

Notice the leaves of mullein, Figure 54. It will be seen that they decrease in size from below upward. They finally become so small that the photograph does not show them. They are mingled among the flowers all the way to the top of the stalk. These reduced leaves we call bracts. They surround dandelions and can be seen reflexed in Figure 88. A whorl of four surrounds a group of dogwood blossoms. In this case they are very showy to attract insects. A beautiful blossom in early spring, the liverleaf that grows from a bunch of last year's three-lobed leaves has a whorl of three green bracts so close to the flower we call them sepals sometimes; the only

harm that comes from this is, it confuses us if we are hunting in a key for the name of the plant. No one can tell every time where bracts leave off and sepals begin; no more can he tell where leaves stop and bracts begin.

We will have accomplished the purpose of this lesson when we see by a study from plants themselves that bracts are only reduced leaves.

Exercise: Begin with the daisies and find as many flowers as you can that are surrounded by one or more whorls of reduced leaves. What is the chaff of oats, wheat, rye, barley, timothy hay and other grasses? See if they are not bracts, little leaves in among the flowers.

LESSON XLIV.

THE LEAF.

Leaves in the Role of Sepals and Petals.

When a whorl of bracts,—reduced leaves, grows very close to the flower we change its name and call it a calyx; and instead of bracts for the separate parts, we say sepals; sometimes these sepals are green; often they are white, yellow, etc., and give its color to the flower, in part, just as the bracts themselves are colored white sometimes, as in dogwood. They are sometimes as small as the separate hairs of the dandelion's down; again they are larger than ordinary leaves as in the lily. Position alone determines whether or not they are sepals. Many flowers have just two whorls of floral leaves, Figure 40; in this case we call the outside whorl a calyx and the inside whorl a corolla. The separate leaves of the corolla are called petals. The sepals and petals of flowers exist under many disguises; they are grown together sometimes. One is

entirely suppressed sometimes, in which case we call the one that is left the calyx; the petals often grow on the sepals; sometimes the petals are very unlike as in the bean, Figure 46, the snapdragon, and many other flowers; so are the sepals. You will often have difficulty in determining which are sepals and which petals. Do not become discouraged at this; experts have difficulty; if you are interested in the naming of flowers you are ready for a work on systematic botany. Gray's Manual is a very good one. Details that would guide you in every case are too numerous for a book like this to give them.

The purpose of this lesson is to point out that sepals and petals whatever their shapes or disguises, are modified leaves. If it seems to you that it is impossible that organs like the spurs of many flowers can be leaves, two things will help you: Study spurs in all sorts of spurred and irregular flowers and see if you cannot arrange a list in which they become simpler and simpler until they fade out; study a very complex flower in younger and younger stages until they are so small you require a lens to see them; are the flowers more regular as they become younger? Are the petals and sepals more alike? We apply this term irregular to flowers that do not have all the separate parts of the same whorl alike.

LESSON XLV.

THE LEAF.

Leaves in the Role of Stamens.

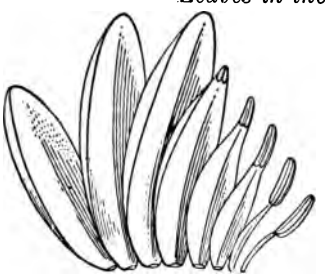


Fig. 69.
The water-lily's petals become stamens. After Gray.

We need in this lesson to know what a stamen is. Figure 69 shows a complete stamen at the right: its stem, its lower part, is called the filament; the enlarged upper part is the anther; the anther bears the pollen; see Lessons XVII and XX. Is the stamen a modified leaf? Students where water-lilies are to be had are especially fortunate for this lesson. Go to the water-lily and see if you do not find something like Figure 69. Here is a gradual transition from a perfect stamen, right hand figure to a perfect petal, left hand figure. Other flowers will show the same thing. I have often seen it in roses. Examine the peony and you will certainly find it.

Exercise: Look at the ends of the innermost petals of roses for anthers on their tips. Gather some wild roses; try to estimate the number of their stamens; compare them with cultivated roses; have the wild rose stamens become petals under cultivation? Cultivation (plenty of rich plant food of the right quality) changes the stamens of many flowers into petals. This is another reason why we think stamens are modified petals. It must not be concluded that in the cultivated flower there is a petal for every stamen in the wild state and no more.

LESSON XLVI.

THE LEAF.

Leaves in the Role of Pistils.

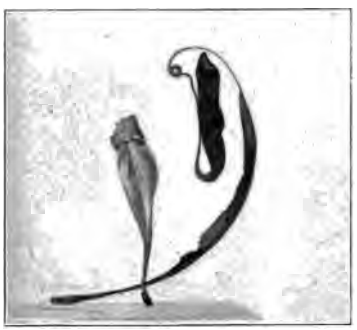


Fig. 70.
A foliage leaf functions as a pitcher and tendril. *a*, An East Indian leaf; *b*, ordinary pitcher-plant leaf.

We have seen, Lesson 43, that leaves gradually change on the same flower stalk into bracts; and that bracts as insensibly become sepals; sepals in turn become petals which again may become stamens. We have also seen that leaves become spines sometimes and we shall see in Lesson LI that they become tendrils. In the pitcher-plant they become pitchers, Figure 70. In a curious plant in North Carolina leaves become traps in which flies are caught. In many plants leaves become scales. All these organs: prickles, tendrils, stamens, pitchers, scales, and the highly specialized foliage leaf itself, are doubtless end results in the transformations of a common leaf-like form. Spines would have to go back to or toward this primitive structure before they could become tendrils or stamens. For the same reason stamens do not generally become pistils; they would need to go back in most cases and set out on the new road which ends in pistils. This is what we should expect, and it is what we generally find.

Exercise: Look on double flowers of all sorts for pistils at the center and see if in many instances they have not become petal-like or even in extreme cases, green leaves again. Find some if you can that are rolled somewhat pistil fashion and with a "style-like apex." Do not be in a hurry to reach this

or any other conclusion to which your books point. Look often and long and let conclusions grow. Examine the petaloid stigmas of the common blue flag.

LESSON XLVII.

THE LEAF.

Leaves in the Role of Bud-Scales.

It will be useful to study this lesson in the spring when the dogwood begins to grow. You will find that growth from below pushes the scales up and four large petaloid leaves take the place of the scales of the flower bud. These were described in Lesson XLIII, and called bracts; the dogwood thus furnishes us evidence that bracts and scales are alike modified leaves—the scale in this instance is the tip of the leaf-blade; it cannot grow and its death produces a notch in the apex of the dogwood's bracts. It clings on for a while, brown, while the bract is white or greenish white.

It is sometimes the stipules of the leaves that form the bud-scales. This can be well seen in the forming of new buds of the magnolia in the fall. It again happens that the bud-scale is the petiole of the leaf. If a sweet buckeye can be found, its bud-scales will show that they are reduced and modified petioles because some of them will be tipped with the remains of the leaflets of its palmately compound leaves. Another reason why we think bud-scales are modified leaves, is, the scales are arranged on the buds in the same order that the leaves are on the stem. Consult Lessons XV and XVI on leaf-arrangement.

Exercise: First learn Lesson XVI thoroughly so you can quite understand the two-fifths arrangement; next examine the arrangement of the petals on a rose or apple blossom and see if it is not the same; now examine the arrangement of the

scales on rose or apple buds and you will find that the arrangement is the same.

Exercise II: Watch the formation of beech and tulip buds and their opening in the spring and see if you can find any reason why their scales are stipules.

Exercise III: Watch the unfolding of lilac buds in early spring and you will see every stage of transition from scale to leaf. See if you cannot tell by the veining of a lilac bud-scale that it is a modified leaf-blade. Note especially the arrangement of leaves on lilac; the leaves are opposite and successive pairs are at right angles to each other. Notice now the arrangement of the bud-scales; is it the same? See Figure 61 a.

Exercise IV: Examine a spray of arbor-vitae. Its leaves are reduced to small green scales closely appressed to the stem; see if there are not two kinds, one on the side and one on the edge of the flat branch. Examine also a spray of cedar for leaves reduced to scales. What are the bud-scales of the Norway maple?

LESSON XLVIII.

THE LEAF.

Leaves in the Role of Bulb-Scales.

A white lily bulb will serve us best for this study. Figure 71 shows one taken up in November,—a good time to study this lesson; any time in Autumn will, however, do. The scales at the bottom are the bases of leaves in which food has been stored up to help in making stem, flowers and seeds the coming year. The leaves which are still green at the top and still function as foliage leaves, are pale and thickened at their bases and function as storehouses of food,—a function of leaves not hitherto noted. Probably there is no leaf that does not in some part and at some time, hold some stored food.

Exercise: Cut across an onion; does each of the several concentric circles you see represent the base of a leaf in which

Fig. 71.

A lily bulb; leaves as storehouses for food.

food is stored? Go for answer to the young growing onion and see if you can trace its leaves to circles in its bulbs.

LESSON XLIX.

THE LEAF.

The Pappus of the Dandelion.

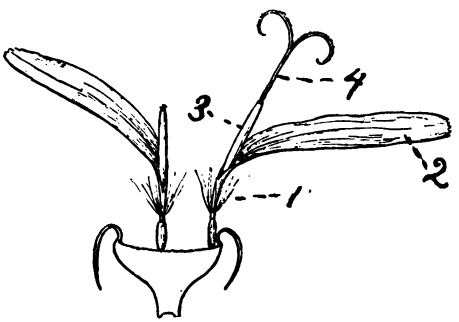


Fig. 72.
A dandelion flower. 1, calyx; 2, corolla; 3, stamens; 4, pistil. After Gray.

Exercise: Get a dandelion that has just fully bloomed; cut the large head in two from above downward so as to split the stem on which it grows. Look at the cut half of the large head and see if it is not composed of separate flowers, many of which look like Figure 72. Compare this part by part with the simple flower in Figure 40 and with the separate parts of a spring-beauty. You will see the same number of separate whorls in them; sepals, petals, stamens, pistils. Similar parts are similarly named in the two figures. The outside member of the dandelion flower is very unlike that of Figure 45, and of flowers generally, but we have already learned that position determines; form cannot, for forms are as different almost as different kinds of flowers. This dandelion down, then, is a modified calyx. But as we have already learned that a calyx is a whorl of modified leaves we are, therefore, justified in concluding that the down which we find on the dandelion seed and which occurs with modifications on many kinds of blossoms is an extreme modification of leaves.

LESSON L.

THE LEAF.

The Blossom End of the Apple.

What are the dead brown appendages at the blossom end of the apple? They seem to be leaf-like; perhaps they are the tip of the calyx.

Exercise: When the apple blooms next, examine the blossom carefully. The parts of the apple are present in the blossom. Some parts of the blossom are dropped, some remain and grow greatly. Mark one definite apple blossom and watch it every day until it becomes a small apple and you cannot help learning that the calyx closes in about the pistil and at last fuses with it and then both thicken together. As the calyx consists of modified leaves and the pistils of modified leaves it must be that the edible portion of an apple consists of modified leaves. You can watch the modification all the way from the leaf to the apple.

Cut an apple across midway between stem and blossom and scrape a little from next to the core; now scrape a little from next the peeling; which is softer and tenderer? See if you can tell by any appearance where the outside and inside meet. Compare your cut apple with Figure 73. The leaves that went to make the apple's pistil were wrapped with the upper side in and when the leaves of the calyx were bent together their upper sides

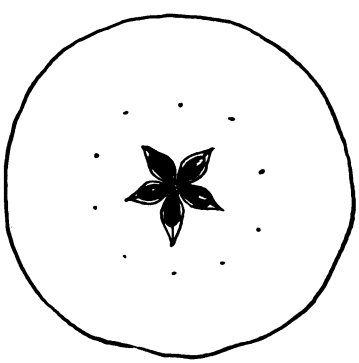


Fig. 73.
A cross-section of apple. Drawn by Miss Helen M. Fiske.

were also in. In eating the apple then you eat the upper side of the calyx leaves and the under side of the pistil leaves. Notice carefully this figure (Fig. 74) of the upper and under side of a leaf and see what difference the two sides present. The upper side at least makes apple pulp that is firmer than the under. The upper side of the leaf is the compact side; the lower is the spongy side.

Exercise: Pull some raspberries and blackberries yourself. Does a portion of the top of the flower stem come off with the blackberry that stays on with the raspberry? When we eat a blackberry we are eating a part of the stem that has

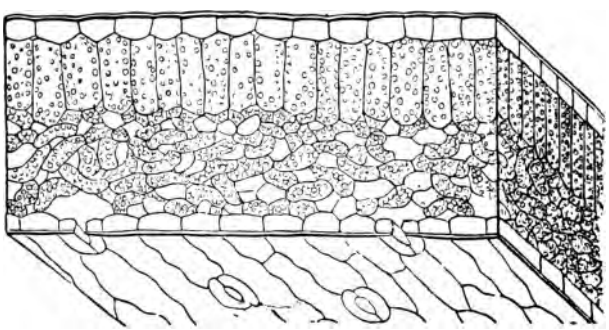


Fig. 74.
A section of a leaf. The lower side is spongy. After Gray.

become fleshy. Examine the seeds of the blackberry and see if the separate seeds are not made on the plan of a cherry, a stone within and the fleshy part without. The cherry has no bloom on it when ripe as the apple has; it is the ripened pistil alone. This pistil leaf has greatly thickened; the outside which is the under side of the leaf has become fleshy and the inside which was the upper side of the leaf has become the hard stone.

Exercise IV: Study walnuts, strawberries and pears from the first appearance of the flowers until they are fully formed

and see what their several fleshy parts are. Try to learn what part of the stem or flower has become the edible portion of every fruit you eat.

LESSON LI.

THE LEAF.

Leaves in the Role of Tendrils.

Figure 24 shows us a greenbriar leaf. Its stipules have abandoned the office of foliage leaves and are entirely given up to support; they appear as tendrils. Sometimes tendrils are modified branches. If they grow out from the wood so as not to strip off with the bark they are modified branches instead of leaves. Compare the distinctions between prickles and thorns, Lesson XLII.

Exercise: Find out by this rule what tendrils are in grape-vines.

Figure 75 is a leaf of a garden-pea; notice that in this case the leaflets of its compound leaf are, several of them, converted into tendrils and that its stipules have grown to the size of leaves to discharge the duties of the green leaf, which the leaflets have laid down in order to support the plant. Examine the sweet pea plant carefully. It has given up its leaflets for tendrils also, but instead of enlarged stipules for leaf surface, it has expanded appendages along its stem; Figure 76.

Fig. 75.
A garden-pea leaf. From Barnes's Plant Life.

Fig. 76.
A sweet pea leaf. Drawn from nature by Miss Helen M. Fiske.

Another way to tell whether a tendril is a modified branch or leaf is by its position. Remember a branch generally grows from a bud in the axil of a leaf,—that is, from the stem just above the leaf. Figure 77 shows a tendril of passion flower in this position. It is, therefore, a branch, not a leaf.

Exercise: Find some tendril-bearing plant not here mentioned and ascertain by one or the other, or both, of the above rules, whether its tendrils are modified leaves or branches.

LESSON LII.

How Tendrils Behave.

Exercise: Find some tendril-bearing plant and note in what direction some tendril points that is nearly grown, but has not yet begun to twine itself about an object. Watch it every ten minutes for a few hours; does it move around in a circle or an ellipse? What can it be doing? Is it hunting for something about which to twine? Let the tendril itself answer; bend a twig over so it will just lightly touch the tendril near its tip and see if it does not stop its movement in a circle and begin to twine about the twig. How long is it before the tendril has taken strong hold on its support?

Examine several tendrils that have taken fast hold on some object and see if Figure 78 represents them correctly. What are the coils between the plant and its support for? Let the tendril again answer; watch its action in a storm and see if the purpose of this can be to yield somewhat to the pull of the leaves so that it may not be suddenly snapped off. May it also be to pull the plant and support closer together?

Fig. 78.

A tendril coiled between plant and support. To pull the plant nearer to the support? To enable it to yield a little in the storm? After Gray.

LESSON LIII.

How the Bean Finds its Pole.

Plant twenty or more twining beans, corn-field beans. As soon as they come up put poles down for them to climb, some five inches away and on all sides of the beans. Watch the beans as they grow and see if they grow up and reach out in some direction as if hunting something. Mark the direction in which they point from hour to hour and see if they swing round in a circle in search of their pole. Do they grow a little longer and reach a little further every round? When they have almost reached the pole at a distance of several inches remove it and see how far the beans can reach. Of course the same experiment can be tried with morning-glories

or any other sort of twining plant; it would be very profitable to try it with several twiners for comparative study. These experiments could be tried on the farm or in the garden in spring at very little cost of time. Let the results grow with the season. If the bean fails to find a pole within supporting distance, does it bend to the ground, establish a new base and begin to hunt in its new territory as before?

LESSON LIV.

The Multitude of Plants. The Struggle for Existence.

Count the grains on what you think is an average ear of corn. I have just found 400 well developed grains on a single ear. This means that one grain can become 400 in one year and this 400 can become 400x400 or 160,000 the second year; and these 160,000x400 or 64,000,000 the third year; 25,600,000,000 the fourth year. One bushel will yield as many bushels as one grain will grains; so one bushel will yield 25,600,000,000 bushels in four years.

The earth's land surface is 52,500,000 square miles. One bushel will plant eight acres and eighty bushels will plant 640 acres, or a square mile and to plant the whole earth would require 52,500,000x80, or 4,200,000,000 bushels. One bushel of corn would yield enough corn in four years to plant the whole earth more than six times over.

Read the chapter, "The Crowd of Animals," in Jordan and Kellogg's "Animal Life."

Exercise: Estimate the number of beechnuts on a beech tree and allowing that each tree will begin to bear at thirty years old and bear at the same rate, how long would it require for the descendants of one tree to occupy the entire United States allowing 1,000 square feet to each tree? Read Chapter III, of Darwin's "Origin of Species." Naturalists are

agreed that every living species, if its food did not fail and it had no casualties from climate or enemies, could in a short time occupy all the available space. This fact makes the struggle for existence inevitable.

Count the seeds of several plants and the eggs of several different birds and insects and calculate their rate of increase and see if you cannot verify this conclusion. In this struggle for existence between plants, every slight help, every noticeable adaptation is important. A plant that has some advantages in the scattering of its seeds might win in this struggle, while other plants without these advantages, however slight they may seem, might fail. We are now to study several ways by which seed dispersal is brought to pass. The student should not forget while working out these lessons that he is dealing with one of the means by which the plant in question has successfully held its own through the ages in the midst of a multitude of plants that would have crowded it out if they could; in the midst of many animals that have lived off of it in part at least, and in the midst of forces,—heat, light, moisture, soil, gravity, etc., that have never been considerate of it in any way.

All the preceding lessons on adaptation to the light, and all the succeeding lessons on various topics may be profitably considered with reference to the struggle for existence. Indeed, whatever the book or lesson, if it concerns itself with any plant or animal it cannot help aiding you in your study to remember: this species has existed on the earth through its ancestors from the beginning. What qualities, what adaptations does it possess that have aided in this long and successful struggle? No one can fully answer this question nor does any one know all the conditions that might help to the answer. The question is not suggested because it is easy, but because it is important. Because men are working on it and because it will help any one to interpret what he sees.

LESSON LV.

SEED DISPERSAL.

The Wind. Winged Seeds.

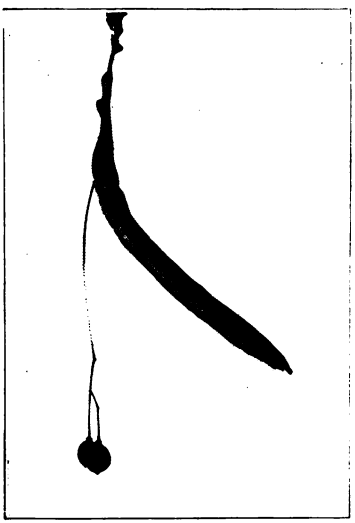


Fig. 79.
Wing-like bract of linden seed.

Figure 79 shows the fruit of the linden, often called linn. This is found hanging on the tree from August to December.

Gather the fruit when it is ripe and compare it with the figure. Drop it from a height when the wind is blowing and when there is no wind. Why does it whirl as it falls? Notice that the leaf-like bract clings to the peduncle for half its length and then leaves it at an oblique angle. Put it down and see whether it lies flat on the ground. Does it lie in such a manner that the wind can easily get under it to pick it up and carry it further?

Gather in the autumn a quart of the seed of sugar-maple. When the wind is blowing, let a boy who volunteers to do so, sow a hand full from the top of the house. Every one who sees will be surprised and pleased. Go to the east side, the leeward side of a maple forest late in the fall and see the sowing of young maples the wind has effected a quarter of a mile or more from the trees.

LESSON LVI.

SEED DISPERSAL.

Other Seeds with Wings.

Exercise: Gather as many as you can of the following tree seeds: ash, hop-tree, Ailanthus, (tree of heaven), water-beech, ironwood, Catalpa and pine. The pine seeds will be found in the space just above the spreading scales of the two-year-

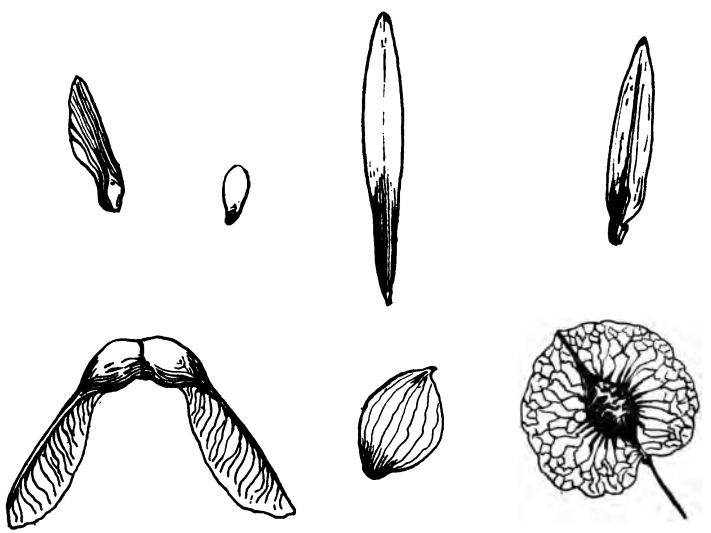


Fig. 80. Fig. 81. Fig. 82. Fig. 83.
Fig. 84. Fig. 85. Fig. 86.

Fig. 80. Winged seed of water-beech. Fig. 81. Winged seed of pine. Fig. 82. Winged seed of ash. Fig. 83. Winged seed of tulip. Fig. 84. Winged seed of maple Fig. 85. Winged seed of ironwood. Fig. 86. Winged seed of hop-tree. Drawn from nature by Miss Helen M. Fiske.

old pine cones. The Catalpa seeds will have to be taken out of their long bean-like pods. All these seeds may be gathered in autumn. The seeds of the elm may be added to this list if they are gathered in the early summer. Compare your seeds

with Figures 80 to 86. Describe them in words or sketch them or write out a description of all of them, giving special attention to the differences between them. What trees or plants do you know by their seeds? Increase this number all you can and you will be doing very valuable nature study.

When these seeds dry, do they warp in such a manner as not to lie flat on the ground? How does this help them? In North Carolina a pine forest will very soon thickly cover an abandoned field. How do the seeds get there? Read Thoreau's essay, "The Succession of Forest Trees," in "Excursions."

LESSON LVII.

SEED DISPERSAL.

The Dandelion's Parachute.

Figure 87 shows many dandelions bearing seeds. Each seed is provided with a parachute to carry it to some distant home. You must consult Figure 89 with dandelion seeds in your hands. How high is the stem that carries these seeds? Measure it and see if it is not a foot or more. You have played with these hollow stems many times, making them into fantastic curls. What are these long stems for? The dandelion flower bloomed right on the ground, did it not? The flower was very heavy; it would have taken a much stronger stem to hold it up than the dandelion has; besides the flower is much safer on the ground than it would be a foot above it, and it can do its work just as well close to the ground. But the seeds to be well scattered must be given to the wind above the grass in which the dandelion grows so that it may not catch and entangle them close to the home blossom, so also *that the wind can* the better get hold of them. We need not

go away from home for wonders; there is not in all the earth a creature more wisely cared for than the dandelion that grows at every door.

Fig. 87.
Dandelions in fruit. Photographed by Prof. J. F. Thompson.

"O'er land and sea I traveled wide,
My thought the world could scan,
But wearily I turned and cried
Oh little world of man.

"I wandered by a green woodside
The distance of a rod,
My eyes were opened and I cried
Oh mighty world of God."

Exercise: Mark a dandelion as soon as it blossoms so that you cannot mistake it for another. Watch it every few hours

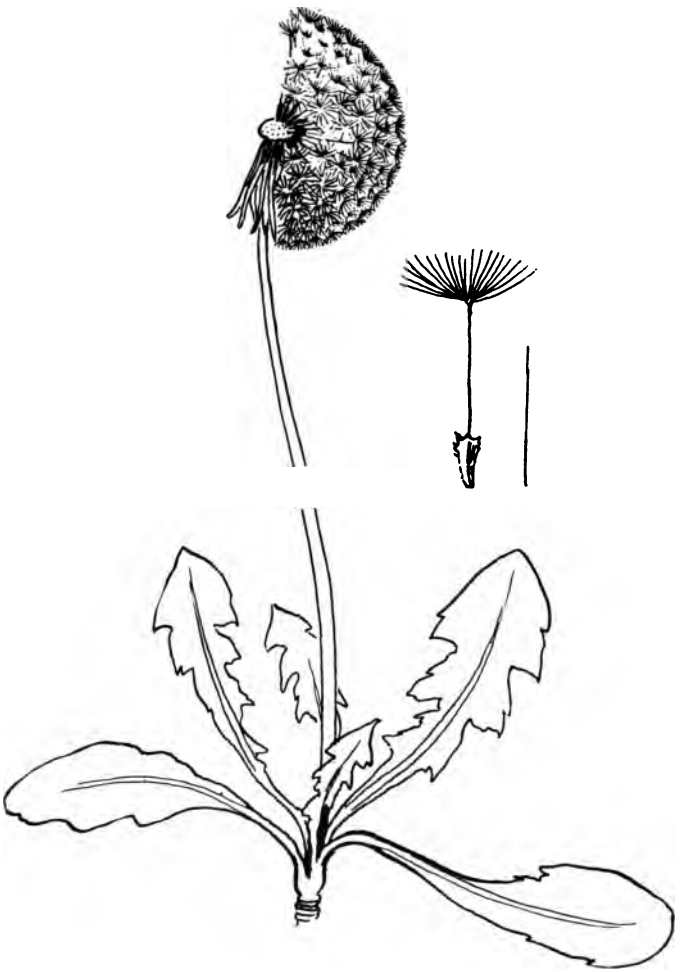


Fig. 88. Fig. 89.

Fig. 88. Dandelion plant. Fig. 89 Dandelion seed. Drawn by Miss Helen M. Fiske.

night and day, and see how quickly when the right time comes, it shoots up and sends its seeds on their dandelion mission.

LESSON LVIII.

SEED DISPERSAL.

Other Pappus-Bearing Seeds.

Figure 92 is a seed of a thistle; Figure 93 of ironweed; Figure 90 of clematis; Figure 91 of milkweed. Compare them all with the seeds themselves. Find all the seeds you can that have some kind of hairy arrangement to make them light

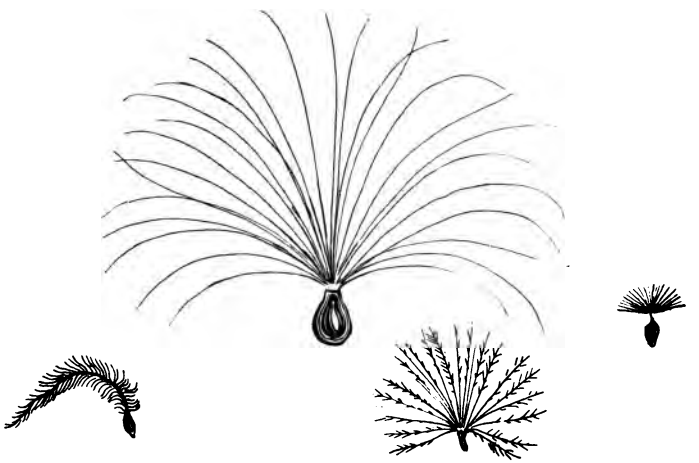


Fig. 90. Fig. 91. Fig. 92. Fig. 93.

Fig. 90. Clematis seed. Fig. 91. Milkweed seed. Fig. 92. Thistle seed. Fig. 93. Ironweed seed. Drawn by Miss Helen M. Fiske.

enough for the wind to carry them. Make collections of these seeds for your home or school in small covered glasses, jelly glasses will do, all correctly labeled with the time and place of gathering them and if you know it, the time of blossoming.

LESSON LIX.

SEED DISPERSAL.

Some Adaptations of the Thistle.

The thistle has no friends in the world; it has taken care of itself for so long that it does not expect anything else; it will be worth while for us to find out how it does this.

Do not try this lesson without thistle seeds that you have gathered for yourself. Notice how very small the seeds are. Collect enough seeds of thistle to weigh a grain. Get your druggist to weigh them for you; break them off from the hairy balloon before weighing. Do not think that it makes no difference how small the seeds are; this is one of the thistle's important secrets of success in the world. If the seeds were larger they could not be sent so far even in its matchless balloon. You must not think that for thistles or men there is an advantage without a disadvantage. This small seed contains all that the thistle that is to be, heirs from its parent thistle. It will take it a long time to get a start. Go again to the pasture where you gathered the seeds and you will see thistle rosettes flat on the ground; they are one-year-old thistles. They have to work a year to make up for the small start they had in the world. Consult Lesson XII on mullein. They are storing food so they will be able to grow a stalk and bear seeds next year.

Every one knows the thistle is armed with prickles; these serve to defend it through the two whole years it requires for maturing its seed.

Exercise: Find in summer the smallest thistle you can. Mark it so you can't mistake it and watch its growth from *time to time till it* bears seeds the following year.

To learn what its balloon is, see Lesson XLIX.

Read Burns's poem, "The Daisy."

"The flaunting flowers our gardens yield
High sheltering woods and wa's maun shield;
But thou beneath the random bield
O' clod or stane,
Adorns the histie stibble field
Unseen, alane."

LESSON LX.

SEED DISPERSAL.

Smallness of Seeds and Spores.

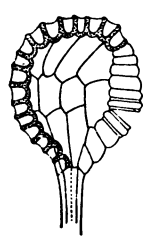
As we saw in the last lesson, smallness of seeds has its advantages. The seed of corn is much larger than that of the thistle. How much larger? Would you rather I would tell you or would you prefer to balance them on as delicate a balance as you can get and find out for yourself?

Because of this good start the corn has in the world, it can be planted in May and it will mature in early autumn. We sow oats in April and harvest it in July. Because smallness or largeness of seed has each its advantage, plants have carried both to remarkable extremes.

Fig. 94.
Fern rootstock with fertile and sterile fronds. After Gray.

The fern gains in smallness by not producing seeds at all, but spores, which grow in spore cups collected into little fruit-dots generally on the under side of the leaf. These fern-spores are so small one can only see them with a microscope. They float in the air as a part of its impalpable dust. They often light on the perpendicular, damp, rock wall of a gorge. Here they grow into small, kidney-shaped bodies, quite unlike ferns.

These bodies bear on the under side rootlets, which enable them to cling to the rock, and male and female cells which unite and form embryos. Fern seeds then are not carried to this apparently inhospitable home, but young ferns are formed there by a minute cell of the fern, which it sends out by the wind for this purpose. The fertilized cell grows at once, and so has no need of seed coats for its protection.



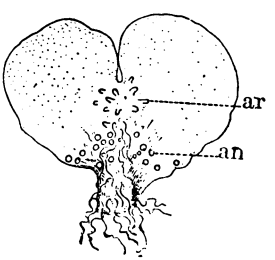


Fig. 95. Fig. 96.
Fig. 97. Fig. 98. Fig. 99.

Fig. 95. Fruit-dots of Figure 94. After Gray. Fig. 96. Cross-section of a fruit-dot of Figure 94. Fig. 97. Sporangium of Figure 94. After Gray. Fig. 98. Prothallium bearing archegonia, antheridia and rootlets. After Gray. Fig. 99. A young fern plant. After Gray.

Exercise: If you cannot learn all this lesson now, you can see the fruit-dots on the under side of the fern leaf, Figures 95 and 100. You can visit the greenhouses and see young ferns, prothallia, they are called, the word is plural, its singular is prothallium, Figure 98; and sometime you can see through the

Fig. 100.

Section of fruit-dot and indusium of maiden-hair fern. x by about 100.

microscope the sporangium, Figure 97, and the spores it contains. You can learn also from this lesson that when you see a plant able to live so extraordinary a life as the fern does on a rock, it is in some way specially fitted to its kind of life.

LESSON LXI.

SEED DISPERSAL.

The Spanish Needle.

We have seen that seeds are variously winged and are scattered by the wind, Lessons LV and LVI, that they are borne up by buoyant, hair-like appendages, by means of which the wind carries them, Lessons LVII and LVIII.

Sometimes they cling by special contrivances with which they are provided, to men or animals, and are carried long distances. The common Spanish needle is one of these, Figure 101. Notice that the barbs extend away from the point of the needle, fish-hook-like; they go in easily, but come out with difficulty. Can any instrument be more nicely adapted to carry out its purpose than these Spanish needle points? How came

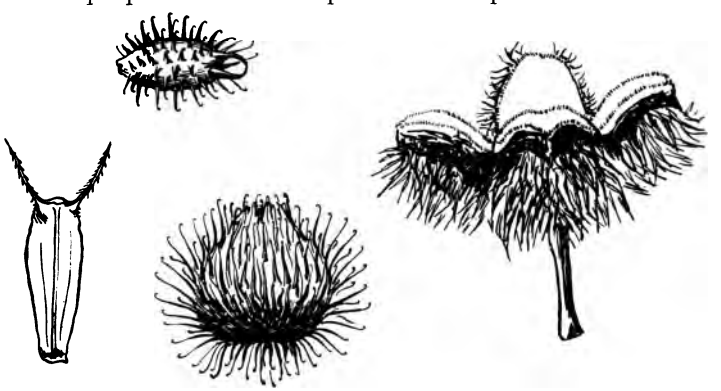


Fig. 101. Fig. 102. Fig, 103. Fig. 104.

Fig. 101. Spanish needle. Fig. 102. Cockle-bur. Fig 103. Burdock-bur. Fig. 104. Chestnut-bur. Drawn from nature by Miss Fiske.

this weed to be thus provided for? When you have really seen into a case of fitness like this, you have as much right as any one to ask this question; you ought to ask it and answer it as well as you can. You had better answer it wrong than not to try to answer it at all.

Exercise: Collect as many kinds of Spanish needles as you can. Are these barbed bristle-points in or out as the seed grows on the stem? How should they be, considering the interests of the Spanish needle? Do Spanish needles sink or swim in water? How long will they swim? Do they have a seed coat that keeps them from becoming soaked for a considerable time in water? Do they grow in great abundance in cornfields that are often overflowed by streams?

LESSON LXII.

SEED DISPERSAL.

Other Seeds that Cling.

Collect cockle-burs, Figure 102, burdock-burs, Figure 103, sticktights, chestnut burs, Figure 104, bed-straw seeds and as many other prickly seeds and burs as you can. You can get a pocket lens that will magnify five or ten diameters from the Bausch and Lomb Optical Co., Rochester, N. Y., that will greatly help you. Talk over with one another the differences between these seeds and their adaptations for sticking. Cockle-burs are very abundant along streams in my neighborhood, where they overflow their banks; are they in yours? Answer all the questions for cockle-burs that are given for Spanish needles in Lesson LXI, especially the question, how many days will it swim? How long will it float in a water current and how far will the current of your swollen stream carry it in this time?

LESSON LXIII.

SEED DISPERSAL.

Currents of Water.

It is intimated in Lessons LXI and LXII that Spanish needles and cockle-burs are distributed by currents of water as well as by clinging to men and animals. Go along your nearest stream and get acquainted with as many plants as you can that grow abundantly and mainly, or altogether there; do not be discouraged if you cannot *name* them all, only be sure that you know them. You will be almost sure to find the great ragweed.

Exercise: In October gather a quantity of the seeds of the

great ragweed or some other river plant bearing smooth seeds. Will these seeds float? How long will they float? How fast does your stream flow in time of flood and how far could these seeds be carried before they will sink? When the seeds have floated as long as they will, will they still grow if you dry them and plant them? If you try these things yourselves, you will not need to be told that currents of water plant seeds in very distant soils. Suppose a new made island is one hundred miles from land. In how many ways that you can think of could seeds get there? Could birds carry them in mud that clings to their feet? Read "Occasional Means of Distribution" in Chapter XII of the "Origin of Species."

LESSON LXIV.

SEED DISPERSAL.

Fruit. The Service of Animals that Eat it.

Crows assemble together sometimes to the number of 200,000 or more and roost through the winter in the same trees; such a place is called a crow-roost. There is a crow-roost in Arlington Cemetery near Washington, D. C. In 1889 Mr. Walter B. Barrows collected all the droppings of the crows from two square feet, and in this material he found 4,764 seeds of plants brought there by the crows. He estimates that on the ground of the entire roost there were 700,000,000 seeds; enough to sow a thousand acres as thickly as wheat is sown. These were the seeds of stone-fruits, like cherries, sour-gum, sumac, etc. The birds had eaten them for the fleshy part. The stones had prevented the seed from being destroyed by the digestive process.

In many parts of our country the mistletoe is found. It grows on branches of oak, elm and other trees many feet from the ground. It could not spread if its seed *were not sown in* these inaccessible places in some way. The

seeds are gummy and cling to the bills of the birds that are eating them. The birds then fly away, wipe their bills on the limbs of distant trees and so plant the seeds where they can grow. Figure 135 shows a section of an oak branch through its own wood and that of the mistletoe growing on it. How are the seeds of raspberries, blackberries, mulberries, wild cherries, Virginia creepers, etc., dispersed? Next time you see a bird eating a cherry don't hurry to throw at it; think of this vast and mutually beneficent relationship between plants and birds. The plants feed the birds and the birds plant the seeds for new plants. Is it not a wise, fair arrangement? Consult Lessons XXV and LXV.

LESSON LXV.

SEED DISPERSAL.

Nuts and Animals.

Have you noticed that walnut trees often grow along fence rows? They are planted there by some animals, especially the squirrel; but as he, for some reason, never returned to claim his hoarded treasure, it has grown into a tree.

Exercise: What birds or mammals feed on acorns, beechnuts, hickory-nuts, chestnuts or hazelnuts? What birds or other animals hoard them for winter use? All these birds or other animals sometimes bury or drop them at distances greater or less from the tree that bore them. Here is our wise arrangement again; it is wiser than we think. It is not artificial. Both parties are vitally interested in maintaining it. In Thoreau's essay, "The Succession of Forest Trees," referred to above, Lesson LVI, he shows that in a neighborhood of oaks and pines, if the pine forest is cut down, an oak forest will take its place because squirrels, birds, etc., will carry acorns to the site of the original pinery. If the oaks are cut down the wind will sow pine seeds where the oaks had

been. Thoreau credits Linnaeus with saying, "While the swine is rooting for acorns he is planting acorns."

LESSON LXVI.

SEED AND SPORE DISPERSAL.

Special Contrivances.

Everyone must know that if you touch one of the ripe seed-pods of a touch-me-not, it bursts with a suddenness and force

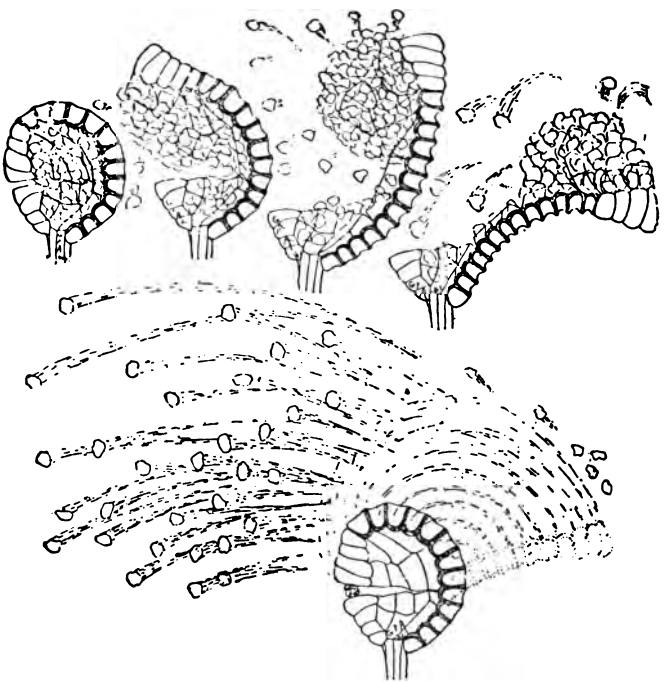


Fig. 105.
Fern spore-case discharging spores. After Atkinson.

that send the seeds to considerable distances. The seed-pods of some other plants do the same thing—as, for instance, the fireweed, which thus gives its sail-provided seeds to the breeze.

Spores are sometimes scattered by similar means.

Figure 105 shows a sporangium of fern, greatly magnified. It will be seen that at the left side in the figure, the cells change in character; here the adhesion is less than otherwheres in the outer circle; the contrivance bursts here; when the cells of the outer ring dry out, their walls tend to collapse and the outer walls being thinnest, give way and a united pull is exerted; suddenly the spore-case bursts and scatters the spores to the wind.

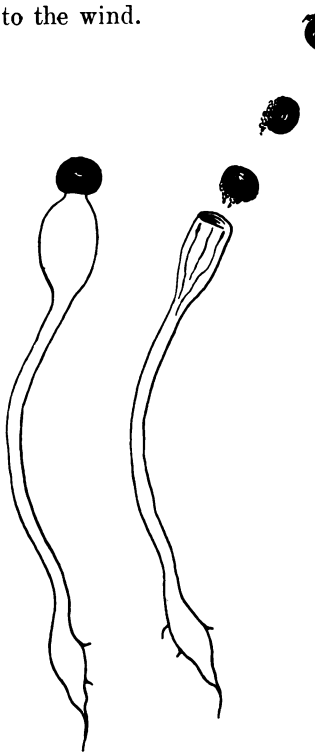


Fig. 106. Fig. 107.

Fig. 106. Pilobolus crystallinus, a mould that has no common name. See text. Drawn by Miss Fiske. Fig. 107. Pilobolus shooting its spore-case into the air and scattering spores. Drawn by Miss Helen M. Fiske.

Exercise: Get some stable manure and put it on wet blotting paper under a bell-glass. This compost contains spores of a white mould that will cover it all over in two or three days. Generally after this dies, in about nine days after the preparation is set, a mould of smaller growth comes up, Figure 106. The black cap at the top is filled with thousands of spores too small to be seen with the naked eye. When the spores are ripe, the enlarged portion of the stem swells out and pulls the part in the spore cap out forcibly and suddenly, sending the cap two feet or more into the air. The spores are caught by the wind and scattered over the grass. Stock eat them and they pass through their di-

gestive organs without damage and if they have warm, wet weather for a few days they grow and ripen again in the droppings of the stock. Everything about their growth can be seen under a bell-glass, except the spores, which require a microscope. They will shoot off their little cannons, hundreds of them and cover the interior of the bell-glass with their little black caps. Get a high bell-glass if you can and see how high they can shoot. A curious thing about the shooting is, the caps always turn over, as shown in Figure 107, and land on the bell-glass spore-side up. When this shooting occurs in the open air the caps, on account of their heavier specific gravity, fall away from the spores and leave them to be scattered by the wind.

LESSON LXVII.

SEED DISPERSAL.

Special Contrivances.

A walnut is round and can roll long distances on a hillside.

Many seeds are rendered conspicuous by being bright colored. This is true of the seeds of dogwood, black haw, wild cherry, and of berries and stone-fruits generally. Black seeds with the snow for a background are especially conspicuous. This is, of course, to attract the birds and effect the dissemination of seeds.

Tumbleweeds break off close to the ground; the weeds are generally round in shape. The wind starts to roll them and sometimes heaps them against obstacles in large heaps; as they roll the seeds are sown over the ground. Figure 108 shows pampas-grass; its tassel shaped tops break off and are carried in the same way, sowing their seed as they go.

Fig. 108.

Pampas-grass; the tassel tops break off sooner or later one way or another and the wind scatters the seeds.

LESSON LXVIII.

SEED DISPERSAL.

A Seed Dispersal Table.

Sometimes edible fruits contain seeds the covers of which are indigestible; these are swallowed by birds and animals and

dropped with their ejecta, Lesson LXIV. Sometimes as in the case of nuts and grain the seeds eaten are destroyed, but the plants bear far more than they need and many are dropped by animals by accident, Lesson LXV. Some seeds are winged, Lessons LV and LVI; some have hairy appendages, Lesson LVIII; some have hooks on the pods, which contain them, Lesson LXI; some float, Lesson LXIII, and some have special contrivances, Lessons LXVI, and LXVII.

Exercise: Try to find a plant with no special help for seed scattering.

Exercise: Fill out the following table for every plant in your neighborhood as the years go by.

	Seeds edible with indigestible seed-coats	Seeds edible but scattered by accident	Seeds winged	Seeds floated by hairs or any form of pappus	Seeds hooked	Float in water	Special contrivance
Walnut		x					x
Sour-gum	x						
Slippery-elm			x				
Thistle				x			
Cockle-bur					x	x	
Touch-me-not							x

Read Chapter IV in Sir John Lubbock's "Flowers, Fruits and Leaves."

LESSON LXIX.

PLANT SOCIETIES.

Water Plants.

Exercise: Visit several forests, especially to see if you find considerable numbers of the same kinds of trees growing in them. Do you know of a maple forest? a beech forest? an oak forest? Where can you find many willows, sycamores, sassafras, gum or other sorts of trees growing together? Do you know of a society of lilies, ragweeds, mallow, blue-grass, cockle-burs or wild roses anywhere? A group of similar plants we name a plant society. Figure 110 on St. John's river, Florida, is a palm society. This island of palms is known as "North Indian Field." It is surrounded by shallow water in which reed societies grow. Locate as many plant societies within a half mile of the school-house or your home as you can.

Figure 109 shows four societies: lilies in the foreground, then reeds; then willows; then deciduous forest trees, oaks. Why do these plants grow together? What advantages come to them because they grow together? Do not be in a hurry to answer these questions. Do not think that you or any one else can fully answer them. You will one day travel in warmer countries than this; in colder; in dryer; in higher. There are places in your neighborhood that are dryer than others; places that have a different soil from others. The south side of a hill is warmer than the north. From what you see at home and away you may easily learn that some plants

Fig. 109.

Four plant societies. Yellow water lilies, reeds, willows and an oak forest from the foreground backward.

grow in the water only or in very wet soils. These are called water-plants, hydrophites; pond-scum, stonewort, duckweed, and white and yellow water-lilies are examples.

Fig. 110.

A palm society and a reed society.

Exercise: See how many different plants you can find that are free-swimming.

LESSON LXX.

PLANT SOCIETIES.

Microscopic Plants.

All natural waters, ponds, streams, lakes and the ocean itself, contain plants and animals so small that single indi-

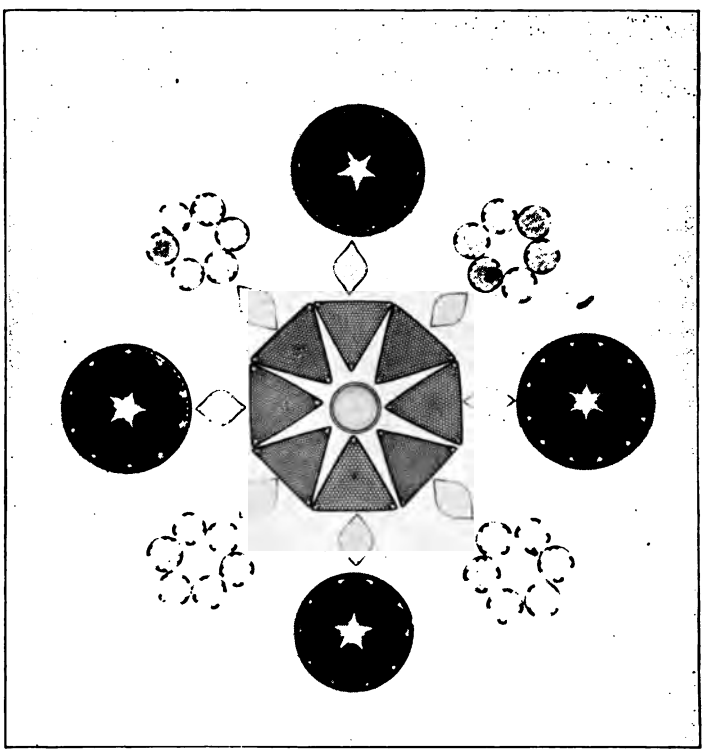


Fig. 111.

Diatom shells. One of J. D Mœller's slides, loaned by Bausch and Lomb Optical Co., and photographed with their one-inch photo-objective. x by about 60.

viduals can only be seen by the microscope. This life is called Plankton. Diatoms, shells of which are shown in Figure 111,

belong here. In all our streams, stones and sticks will be found covered with a gelatinous, sleek, yellowish-brown layer; this consists of millions of diatoms; there are also numberless free-floating forms; their walls are made of the same material that sand is,—silica. These plants have died in lakes and bays in past ages in such numbers as to make rock formations several feet in thickness and many square miles in extent. The shells are sometimes so small, Figure 112, that 41,000,000,000 can occupy a single cubic inch. Many kinds of diatom shells are beautifully sculptured, and have been much studied on this account. Thousands of different kinds have been described and figured.

Fig. 112.

Infusorial earth. These cylindrical diatoms shown from both the side and the end are so small that 41,000,000,000 can occupy one cubic inch. x by about 500.

Exercise: In March every stone and blade of grass in a stream near my house is covered with this yellowish-brown growth to the thickness of half an inch or more. Find this, pass it through your fingers, and if possible, look at a little of it under a microscope. The quantity of microscopic life in a lake or other body of water is important, for it determines the amount of higher life—fishes, for example, that it can support.

LESSON LXXI

PLANT SOCIETIES.

One Plant Adapted to Live in the Water.

Figure 113 is a view near Syracuse, Ind., in a bay of Turkey lake. In the view here shown there were hundreds of water-

Fig. 113.

Water-lilies. Syracuse Lake, Indiana, a bay of Turkey Lake.

lilies. The lake was of varying depth from one to something like four feet. These large leaves and flowers grow from root-stocks buried in the mud at the bottom of the lake in which the food necessary to produce them had been stored up. In this way the stem is preserved from all danger. The leaves and flowers all seem to have stems just long enough to bring them to the top of the water. Pull some of them up or row

Fig. 114.
Surface view of stomata and epidermis of the pie-plant. x about 200.

out to where the water is clear enough to permit you to see to the bottom, and you will find that they are much longer than long enough to reach the water's surface; the extra length of the flexible stem enables it to bring leaf or flower to the top in varying depths; they can thus ride on the crests of the highest waves that are likely to come on the lake. They are buoyed up by air-cavities that make them lighter than the water. These cavities serve also to conduct air down to the

stem. Figure 115 shows such cavities in a kindred species. Figure 114 shows the stomata of leaves under a high power of the microscope. It is through these openings that air enters the leaves. In Lesson XXXV there is a cut of a cross-section of a stoma. Most leaves have these openings more numerous on the under side. This is, of course, not possible for the water-lily; its stomata are all on the upper side; an adaptation to its life in the water.

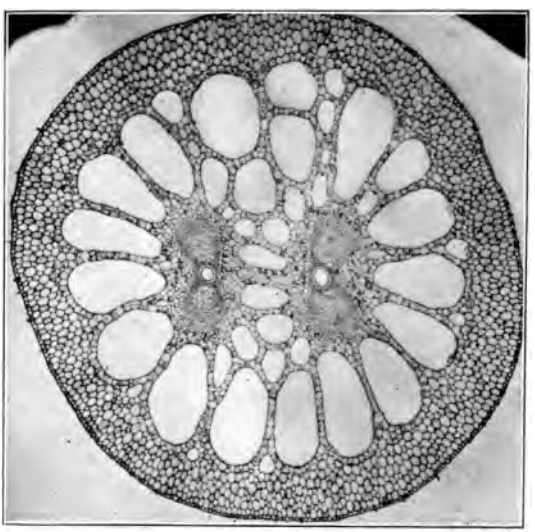


Fig. 115.

Brassenia; cross-section showing air-spaces from stomata to parts under water. x by 20.

Exercise: Find water-cress and compare its stem for stiffness and toughness with the stem of several air-plants of about its size. Take stonewort from the water or any other plant that grows upright in the water, and try to make it stand erect on land. Its weak stem is nicely adapted to support in the water, but it cannot stand in air.

LESSON LXXII.

PLANT SOCIETIES.

Desert Plants.

No life is possible in an entire absence of water, but certain adaptations enable plants to live for long periods without rain.

Fig. 116.

Agave sisalina, nearly ready to flower. One million seven hundred thousand dollars worth of sisal hemp, the fibers of Agave have been shipped in a year from Progreso. Notice the 5/8 arrangement of its flowering branches; the 9th over the 1st.

They sometimes have, under a tough and close exterior which reduces transpiration to a minimum, spongy tissues adapted

to hold water for a long time. The lichens that grow everywhere on stones and trees have these qualities to a considerable extent. The century-plant is one of the most widely known plants that has its home in arid regions.

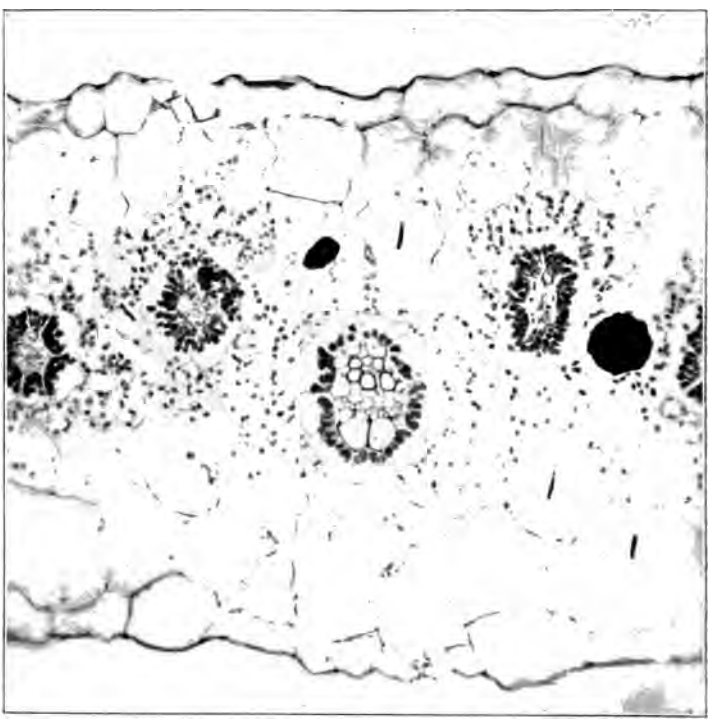


Fig. 117.

Cross-section of a purslane leaf. Notice the large reservoirs for water, between epidermic and chlorophyll cells. Does purslane flourish in dry weather? x about 200.

Exercise: Cut across an Agave leaf and notice the leathery outside to check the escape of moisture, the spongy inside to contain it and the strong spines to ward off the attacks of browsing animals. Notice the reduction of surface in propor-

tion to the size of the plant. Why do corn blades and mosses roll on a dry day? How does this affect the exposed surface? If it reduces it, it checks to that extent the escape of much needed water. Figure 117 shows a cross-section of a leaf of purslane; a widespread plant that flourishes in the dryest season we have, and that every gardener knows is not easy to kill out; our figure shows why; the large cells labeled 1, are water reservoirs. These adapt the plant to our August weather.

Read Charles Dudley Warner's "My Summer in a Garden" for a literary man's view of "pusley."

LESSON LXXIII.

PLANT SOCIETIES.

Adaptation to Moisture. Land Plants.

Between the reed growing in the water and the cactus on the arid plain, we have plants adapted to all degrees of moisture. Mosses grow best where the soil is wet. In a very rainy country like Scotland this may be on the tops of high hills. Cattails and other reed like plants grow in a foot or less of water or on the muddy shoals that immediately surround water. Willows and sycamores grow in soils that may be termed anything from damp to dry; while many grasses and herbs and forest trees and shrubs grow in soils that we call swampy and on dry hills as well if precipitation is distributed somewhat evenly throughout the year as it is in most of the United States. Conditions like ours are termed mesophytic conditions and the plant societies are called mesophyte societies. As compared with the extreme water plants and desert plants, ours are vastly greater in variety, in abundance, and luxuriance of growth. The great characteristic of meso-

phytic vegetation is its expanse of green leaves. Figures 2 and 3 show us mesophytic landscapes in their winter condition. The backgrounds of Figures 109 and 113 in their summer condition.

LESSON LXXIV.

PLANT SOCIETIES.

Some of the Advantages of Mass Life—Society Life.

1. Cross-pollination with all its advantages occurs when large numbers of plants grow together.

2. Small patches of herbs might be wholly stripped of seeds by animals and the species might thus be stamped out in a community, while larger areas could supply the demand and still have seed enough left. This reason applies, of course, to ravages of insects as well as other animals.

3. Forests often resist a storm that easily uproots single trees that are larger and stronger, but unsupported.

4. The competition of forest life brings every tree that survives to its best.

5. The leaves that are shed and the limbs that fall make a covering for the ground that helps to retain moisture.

6. The combined shade of a forest also helps to retain moisture.

7. Is a tree warmer in the forest than in the open field?

8. Do the conditions mentioned in 5, make the soil richer in the forest than it is about a tree in the open field?

LESSON LXXV.

PLANT SOCIETIES.

A Walk in the Woods. Forestry.

Select for this walk a day when the ground is sufficiently dry after copious rains have fallen. Get entirely out into a primitive forest. Leaves and sticks will be found entirely to cover the ground to the depth of several inches. Rake these aside and see how they conserve the moisture, prevent quick evaporation. Visit a large tree that has blown up recently by the roots; estimate how deep in the ground the roots certainly go. Is not each one of these roots and rootlets a water way to conduct the rain down into the ground? Does the forest not make of the ground a gigantic sponge that receives and retains water which would otherwise hurry back to the rivers and oceans? At another time visit an old mill site that no longer has water enough to run it. How many of these can you hear of in the neighborhood. Find out from the oldest settler about the springs that now are dry. Visit one. How many spring-houses are there in the neighborhood that now are without springs? It does not follow from all this that no forests should have been cut down. We had to have much of the ground for grain, but it does follow that we need forests; more than we have. They should be planted on the hills, the poorest land. We should begin to learn that before long we shall be compelled to plant forests as the old world has had to do.

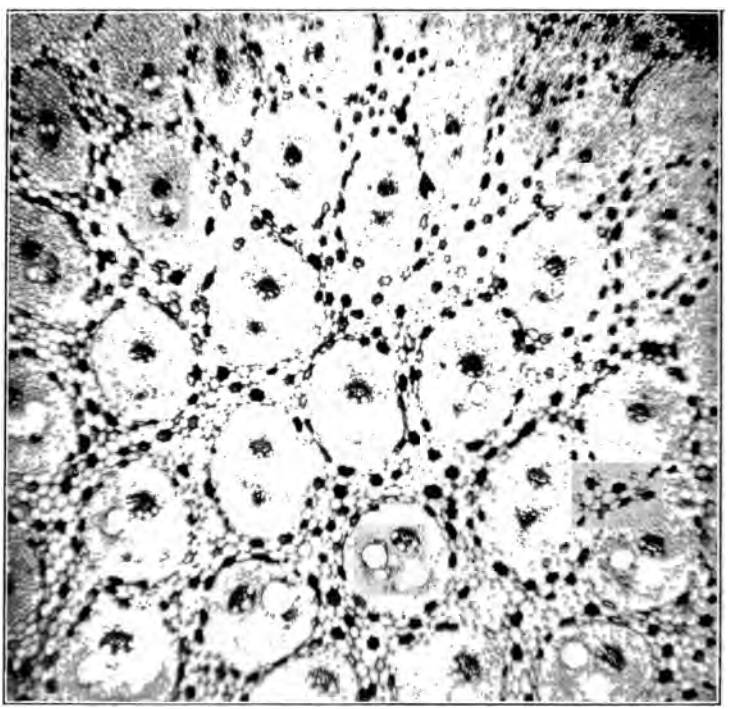


Fig. 119.

A cross-section of smilax stem showing the bundles scattered in the pith. x 30.

LESSON LXXVI.

STEMS.

The Fibro-Vascular Bundle.

Every one has whittled a cornstalk and seen the strings tougher than the pith, irregularly distributed through it. These are called fibro-vascular bundles. Figure 118 is a cross-section of such a bundle from smilax. It contains large vessels arranged in the shape of a V, through which the sap rises to the leaves and flowers above. Beside the large conducting tubes two other kinds can readily be distinguished, the small, thick-walled fibres, enclosing the rest and some irregular-sized tissue which is generally to be found on the side of the bundle next to the bark; in this bundle the upper side, the open angle of the V. This is called the sieve tissue.

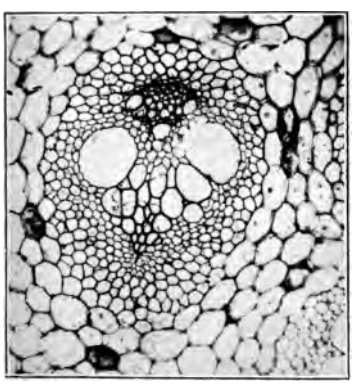


Fig. 118.
A fibro-vascular bundle of smilax. See text. x by 80.

Exercise: Cut off stems of the following plants: corn stalk, Trillium, lily and geranium, and set them in bottles of water that has been colored with a little eosin,—red ink will do. After a few hours, and then daily for several days, take some of them out and split them lengthwise and see if you can determine that the sap is rising through these fibro-

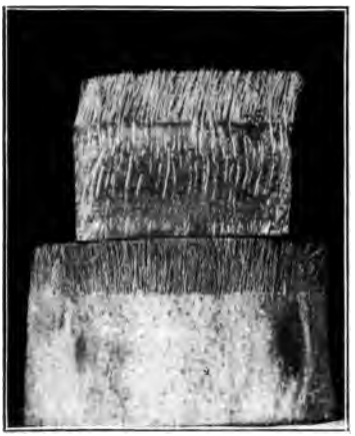


Fig. 120.

Brushes made from the stem of the saw-palmetto. The pith has been combed out and the fibro vascular bundles are tough enough to be useful as brushes. These brushes are made in Melbourne, Florida.

vascular bundles. Let some of these stems have white flowers on them and see if, after a time, the red color does not appear in the veins and veinlets of the floral leaves. With a microscope the vascular tissue can be traced all the way into sepals, petals, stamens and pistils; you can often trace it all the way by the tracks of red with the naked eye. The right flower in Figure 52 was striped in this way within three hours after it was placed in the ink.

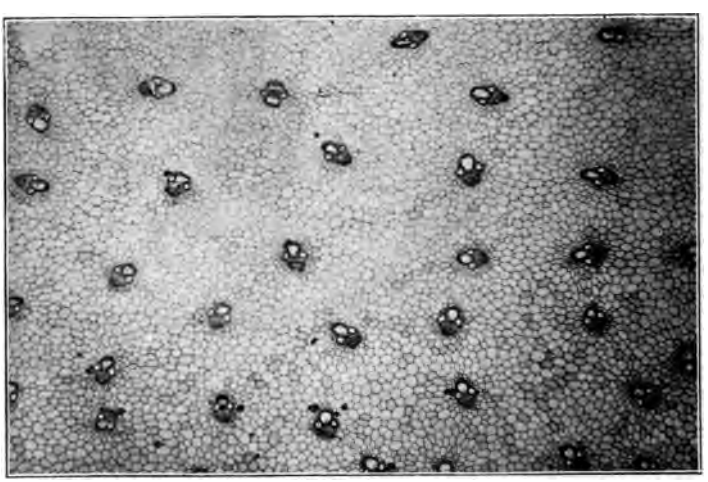


Fig. 121.

Corn bundles distributed irregularly as in smilax and palm. x about 30.

Exercise II: Get a geranium leaf and break its petiole by a steady pull, but do not allow your hands to separate more than a quarter of an inch. The vascular ducts in the geranium are wound about by spiral bands tougher than the rest of the tissues; these will uncoil and the lower end of the petiole will be suspended by these coiled threads.

LESSON LXXVII.

STEMS.

The Arrongement of Fibro-Vascular Bundles in Exogens.

Fig. 122.

Cross-section of geranium stem. Fibro-vascular bundles in a definite circle with pith cells (medullary rays) between. x about 18.

Cut across a geranium stem one year old and compare the cut end with Figure 122. The wedge-shaped bundles a, are fibro-vascular bundles. Notice that they are arranged in a circle around central pith in the geranium stem while they are irregularly scattered through the pith in the corn and smilax stems. This arrangement of the fibro-vascular bundles in rings is seen in all our forest trees; it is the exogenous structure, the pine structure, the oak structure. Compare the next

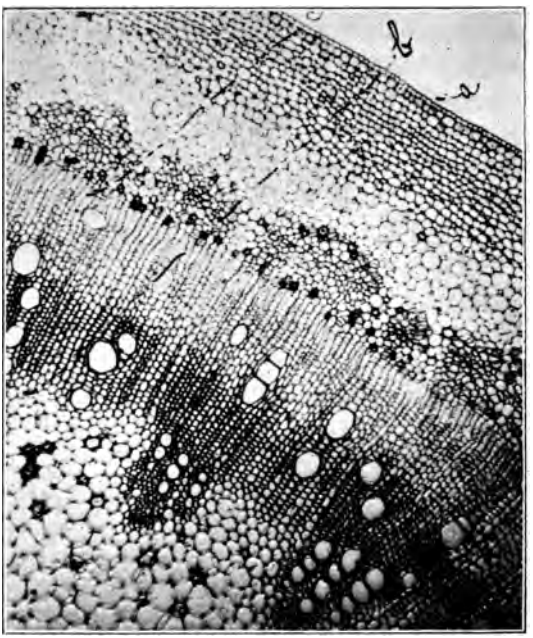


Fig. 123.

A fibro-vascular bundle of Figure 122, more highly magnified. Pith at the left, then wood, cambium *c*, and outside of it the various elements of bark.

lesson. The irregular disposition of these bundles in smilax and corn pith acquaints us with the palm structure, the endogenous structure.

LESSON LXXVIII.

STEMS.

The Growth of Wood in an Exogen.

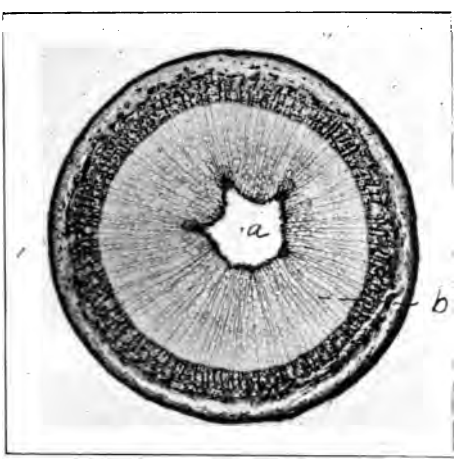


Fig. 124.

A cross-section of a one-year-old stem. It shows from within out pith, wood crossed by medullary rays and bark. Slide and photograph by Mr. George Bond. x about 18.

Cut across a one-year-old stem or branch of almost any tree; Figure 124 is taken from willow. Compare your cross-section with it. There is a center of pith nearly white, a; a ring of wood made up of the woody part of fibro-vascular bundles, b; and a ring of bark. Figure 123 shows a fibro-vascular bundle in detail and we cannot learn about growth in a tree without a little study of it. The part from c, to b, containing the large clear openings, is wood tissues; from c to a, is bark tissues. Growth occurs at c, here the wood thickens on its outside and the bark on its inside; c, is the cambium layer. Figure 125 is a three-year-old stem. The pith is the white center; the wood is the three definite, half-inch, light rings that surround the pith; the dark, outer portion is the bark; the lines that mark so sharply

the divisions between the three portions of wood are caused by the fact that the cells are small and thick-walled in the fall when growth stops and large and thin-walled in the spring, when growth begins. The rings of growth accord-

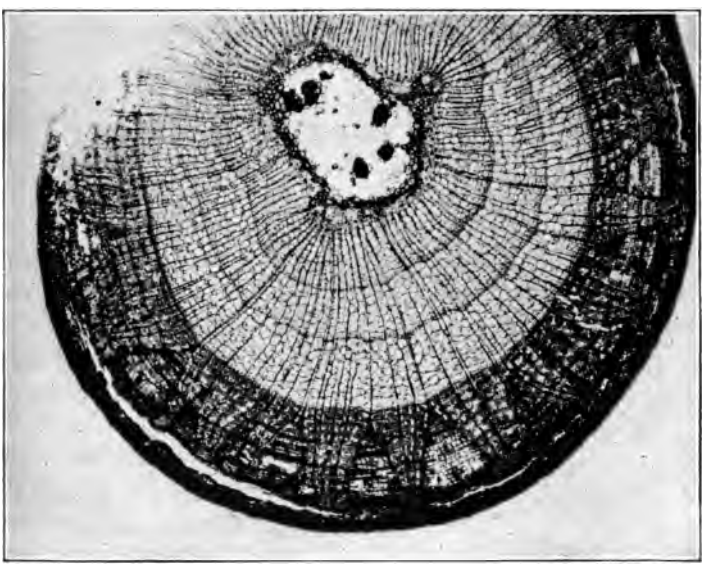


Fig. 125.

A three-year old exogenous stem. It shows in addition to what Figure 124 does, the three rings of growth. x 18.

ingly, however numerous they they may be, are made up of circles of the wood portion of the fibro-vascular bundles, and each ring stands for one year's growth.

Exercise for a school: Saw off a section from the largest log in the neighborhood. Find out from a carpenter how to polish and varnish the end. Count the wood rings, every one of which stands for a year of growth. Now count from the

outside 411 rings and mark the ring that shows how large the tree was when America was discovered; mark in the same way its size when Washington was inaugurated, when Lincoln

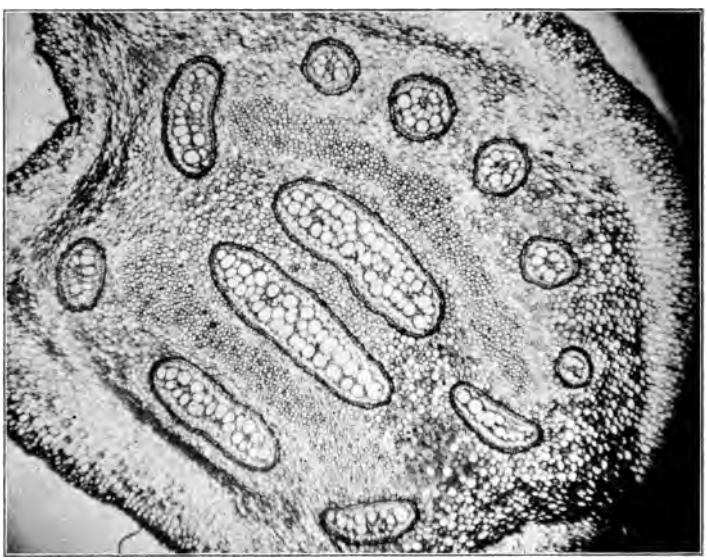


Fig. 126.

A cross-section of a rootstock of fern showing its bundle-arrangement. x 18.

spoke at Gettysburg, etc., for other important events of our history. There is such a section of a large tree in the South Kensington Museum on which more than a thousand years of English history are chronicled.

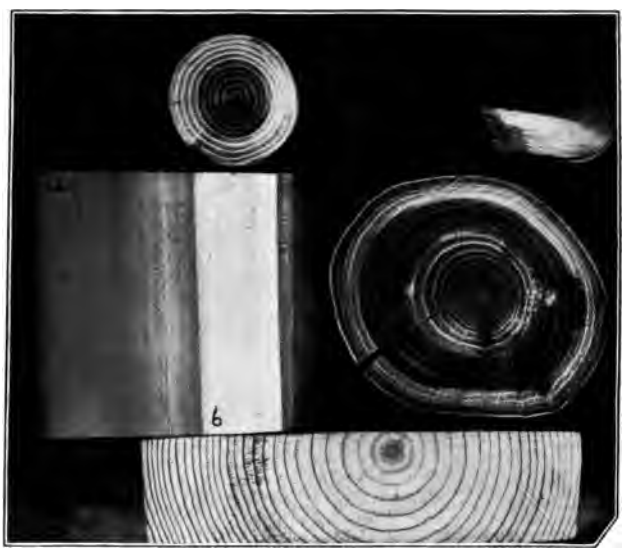


Fig. 129. Fig. 128.
Fig. 127.

Fig. 127. The heart-wood, *a*, sap-wood *b*, and bark of poplar (tulip). Fig. 128. Rings of growth in red cedar. Fig. 129. Rings of growth in the hickory. All these above a pine board that shows rings of growth well.

LESSON LXXIX.

STEMS.

Quarter-Sawed Oak.

Notice in the cross-section of oak and mistletoe, Figure 135, upper piece, there are radiating lines which run out from the pith toward the bark. These are called medullary rays. Quar-

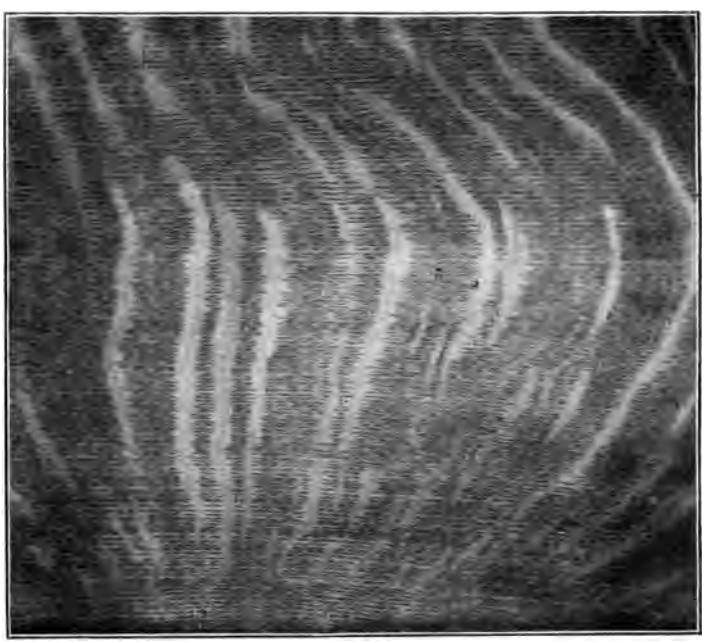


Fig. 130.

Quarter-sawed oak. The wide, perpendicular markings are the medullary rays as they appear in a radial section.

ter-sawed oak is oak that has been so sawed that the saw passed in the plane of these rays; that is from the pith to the bark. The log is first quartered then a board or two is sawed

off from the side of a quarter and when the grain begins to run out a triangular piece is cut off thicker at the bark so as to again bring the saw into line between the pith and bark. Figure 130 shows a quarter-sawed plank. These peculiar markings are caused by the medullary rays. When the tender end of a growing shoot is examined it is found to be all pith. The fibro-vascular bundles grow up later in the pith; this leaves pith cells between fibro-vascular bundles. These are the medullary rays. They do not look like the wood-cells and although single cells cannot be seen by the naked eye, masses of them can be.

In Figure 122 the pith between fibro-vascular bundles shows well the medullary rays. As these bundles become more and more numerous the medullary rays become narrower and narrower; the radiating lines in Figures 124 and 125 show medullary rays as they appear in cross-section.

Exercise: Sketch medullary rays as they appear to the naked eye in cross, radial and tangential sections of some wood. A radial section is made when the knife or saw extends from the pith to the bark. A tangential when it is at right angles to a line from pith to bark.

LESSON LXXX.

STEMS.

Heart-Wood.

Find a tree somewhere that is hollow at the butt and yet is still apparently growing and healthy. The wood usually found at the tree's center and that has rotted and disappeared in this case, is the heart. See Figure 127 for the heart-wood a, the sap-wood b, and the bark of the poplar, (tulip). If you are not perfectly familiar with heart and sap-wood, cut into a tree

or large limb and see the difference in color of the two. Notice that the sap-wood is softer than the heart-wood; it is also lighter; the reason for this is the tissues of the sap-wood are younger and thinner walled. The heart-wood is not alive.

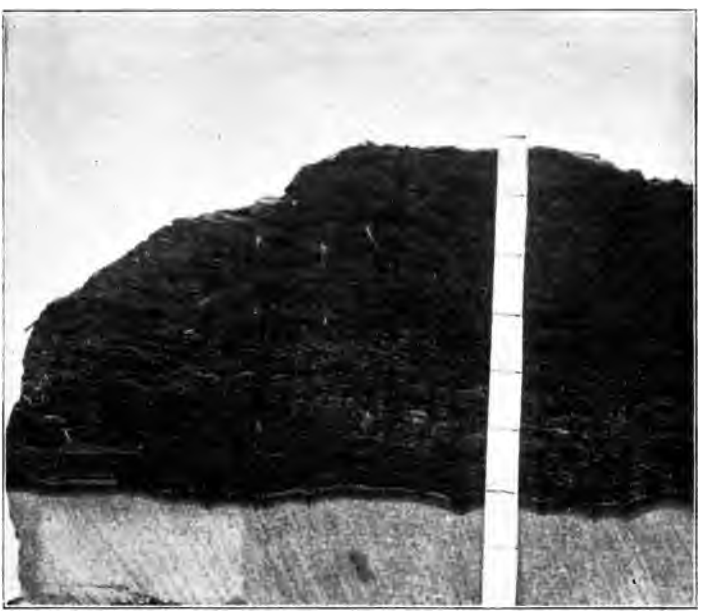


Fig. 131.

Bark of Sequoia. In this piece it is six inches thick. The marks on the white strip are one inch apart.

Layer by layer the wood-tissues grew when the tree was young as explained in Lesson LXXVIII. The innermost layers were of course the older. Finally layer by layer it began to die on the inside, as it grew on the outside. Life and death have thus followed each other from within out, always separated by about the thickness of the sap-wood. Holmes says:

"In fact there's nothing that keeps its youth
So far as I know but a tree and truth."

It would seem from the above that a tree does not keep its youth. Life is confined to a narrow zone on the inside of the bark and the outside of the wood. The heart is the ancestry of the living wood; the dead outer bark of the living bark. The wood entombs its forefathers; the bark in one way or another sheds them. The entombed heart-wood strengthens the tree against storms. The bark dead, but not yet shed, protects it against blows and cold and heat and wet and bark-eating animals. Figure 131 shows the bark of the Sequoia gigantea, the big tree of California. This specimen is six inches thick.

Exercise: Determine the number of years of growth of any tree; wet or varnish a smooth cross-section and you will be able to count its rings of growth.

LESSON LXXXI.

STEMS.

Stem Disguises.

A stem bears leaves, and roots grow out from it. These offices declare a vegetable structure, a stem. It does other things, as for instance, it serves as a storehouse for food; other parts of the plant do this also; but only a stem bears leaves and roots. Armed with a dictum like this we can recognize it under its varying forms. Figure 55 shows an underground stem. It has its advantages in the struggle with frosts and storms and rabbits; but the giants of the vegetable kingdom have got on otherwise. This was not a winning way. The stem is prostrate on the ground sometimes; this is the

case with the stem of the saw-palmetto; it floats under water sometimes, as in the case of Chara; it climbs by many methods, but all climbers are dependent. The princes of the vegetable world relied on none of these methods. At great expense to themselves they stand among their equals. The vine can only go where the oak has first gone.

Exercise: Find the stem of fern, Solomon's-Seal, bloodroot, violet. Is the Irish potato a stem or root? the sweet potato? the artichoke? the Indian turnip? Those are stems that bear buds or leaves.

LESSON LXXXII.

STEMS.

Why the Yellow Violet Comes so Early in the Spring.

"Of all her train the hand of Spring
First plants thee in the watery mould,
And I have seen thee blossoming
Beside the snow bank's edges cold."

Our common violet blossoms early also. The goldenrod does not bloom until autumn. We are entitled to ask why; but the plants themselves are the only authority on the subject.

Exercise: In early spring, gather the following flowers, dig every one up by the roots: Spring-beauty, wind-flower, liverleaf, pepper-and-salt, lamb's-tongue, trillium, violet, bloodroot, crowfoot and twinleaf, and any other kind of flower you can find blooming with or before them. Do they all grow from bulbs or thickened rootstocks or roots? some underground source of nourishment? Can this be the reason why they can bloom so early? Does the crocus come early and from a bulb? Does the tulip? Does the lily-of-the-valley come from a rootstock?

Provided as all these plants are with nourishment on which

to grow they can bloom at once as soon as spring opens. Starting with only the patrimony of a small seed, of course the ragweed must have a long time in which to develop green leaves and roots and gather the necessary food for the exhausting process of seed-bearing. It should further be noted that all these spring flowers are content with small stature. If they wasted their substance in growing large stems they could not bloom so early.

But why should these spring flowers be in such a hurry? Several considerations are worth while in answer. If all plants grew at once and in similar places, there would not be room for them all. Where do you find these little spring flowers? Is it not in the woods and before the trees get their leaves? They must make hay, their flowers and seeds, while the sun shines. Three weeks later and they could not see the sky at all. It is by fitting in to this one little niche of place and time that they can live at all. Patrimony, haste and smallness give us the fleeting beauties of our April days.

You may sometime visit a tropical forest, that is always green and growing and so forever casts its dense shadow. You will find no spring-beauties or any other kind of flowering herb there. Everything that flowers has had to climb as the forest climbs. Instead of small shrubs and annual herbs, you will find vines that can mount up to sunlight on the top of an Amazonian forest.

LESSON LXXXIII.

STEMS.

Bark.

If the birch tree is in your neighborhood notice that the bark easily strips off in horizontal strips. Find a shagbark hickory and notice that its bark peels off in vertical strips that

come loose first at the bottom. (Is this to make climbing the tree difficult for the protection of the nuts?) Notice that the sycamore occasionally sheds its bark and comes out in a new dress. What is cinnamon? Notice the ironwood and see that its bark is shredded up and down the stem, the strings being very fine. Notice the bark of the sour-gum, persimmon, sugar, elm, oak, locust and walnut and see if they are not variously cracked and split up. How many trees can you tell by the bark? It would be fine nature study work for you to learn to tell them all this way.

Why is the bark not as thick as the wood if a layer grows every year, as explained in Lesson LXXVIII. Why does the bark split on the tree in these various ways? The tree has a bark when it is very young. Its outer bark is dead; as the tree grows would it not be obliged to split? The bark of some trees clings much longer than that of others, but sooner or later and for one cause or another, the outer bark of all trees is lost.

Exercise: Compare for thickness of bark red-oak, sugar-maple, beech, walnut, tulip and sycamore; trees of about the same size should, of course, be selected.

LESSON LXXXIV.

STEM STRUCTURE.

Ashes.

Every one knows that when we burn wood we have ashes left. Ashes consist of minerals of one sort and another. In the pioneer days there was a "hopper" at every house, in which ashes were leached to get "lye" for soap making. The "lye", "alkali", "potash" of the ashes acts on the grease in such a way as to make soap and glycerine. We sometimes, when rain-water is scarce, make use of ashes to soften hard water, that

is, to take the lime and magnesia out. The mineral matter of plants is absorbed from the soil in the water. The water escapes in transpiration and leaves the mineral matter behind. Consult again the lesson on transpiration, Lesson XLI. All summer long water, containing mineral matter, is absorbed by the roots of plants and given off in the form of vapor by transpiration, leaving considerable quantities of minerals in the plants. The same quantity of beech leaves burned in October will leave two and a half times as much ashes as if burned in May. Plants cannot grow and mature if they are deprived of these minerals; that is, if they are supplied only with distilled water. Plants deprived of potash lose the power to make starch. If they are deprived of iron the green coloring matter does not work properly. The living matter in plants always contains phosphorus and sulphur. We do not know all the duties of all the minerals in plants. Scouring-rushes owe their roughness to silica in the stem. This protects them somewhat from animals that would eat them. Some grasses are protected in the same way.

LESSON LXXXV.

The Root.

The forms of the root are simpler than those of the stem. Why is this so?

The turnip, the radish, the parsnip, etc., have one main descending root called the tap-root with subordinate branches. Other plants have many co-ordinate roots growing out from the stem in all directions. Roots are sometimes thickened and contain nourishment stored up for the plant the following year, as in the case of the carrot, rhubarb, etc., or for new plants as in the case of dahlia or sweet potato. It may give us some trouble to determine whether these underground forms are stems or roots. If they bear buds like the Irish potato and

artichoke, they are stems. If they bear leaves like the onion, lily and the rootstocks of ferns, Solomon's-seal, and bloodroot, they are stems.

Another office of the root is to hold the plant to the soil or other support. The power of the root to force its way through the hard earth is remarkable. The advancing root is pre-

Fig. 132.
Aerial roots of rubber-tree, Palm Beach, Florida.

ceded by a root-cap which protects the growing point as it advances and penetrates the earth in its front. The poison ivy is held to its support by aerial roots that grow from the stem above ground. Aerial roots may be seen in Indian corn, in the rubber-tree of Florida, Figure 132, and in the famous and everywhere pictured banyan of India. The roots of this

tree descending from branches form additional trunks so that one tree may make a colony covering as much as ten acres.

Still another office of the root is to absorb moisture; this is done by the young root-hairs which are produced continually on the younger parts of growing roots. These hairs come with the leaves and possess in the aggregate a surface in proportion to the leaf surface. This is why it is so difficult to successfully transplant a plant in full leaf. The absorbing root surface is lessened greatly by the injury to root-hairs, while the transpiring leaf surface remains the same. If plants are transplanted in the fall or spring, only so much leaf surface is called out when the growing time comes as corresponds to the root-hair absorbing surface.

LESSON LXXXVI.

Why Clover Helps the Soil.

It has long been known that clover rejuvenates the soil. Farmers sow it in worn-out fields. The reason why this enriches the soil has been lately found out. Bacteria live in the tubercles, Figure 133, that grow on the roots of the pea, vetch, clover and some other plants. They have power in their growth to take nitrogen from the air for food; no plant or animal can live without nitrogen. When this becomes scarce in the soil ordinary green plants cannot grow well as they cannot take nitrogen from the air. It is equally true that no living thing can exist without carbon. Bacteria, as has been shown, cannot get this from the air. The bacteria growing in the clover root give us a fine instance of symbiosis; the clover takes necessary carbon from the air for both itself and the bacteria. The bacteria take the necessary nitrogen for both themselves and the clover and when the clover is plowed

under, all the nitrogen of both is handed back to the soil in their decay.

Fig. 133.

Vetch showing tubercles on its roots in which bacteroids live.

Exercise: Find these tubercles on the roots of clover, vetch or some other leguminous plant.

LESSON LXXXVII.

USES OF PLANTS.

Plants and Starch.

We owe all our starch to plants. We obtain it from the seeds, stems, roots and leaves; our main supply comes from seeds. It is very easy to detect starch; it turns blue or black when treated with a solution of iodine.

Starch is insoluble in cold water; a seed may therefore get wet and dry without loss to its food supply. Plants, however, cannot take solid food; but starch is easily converted into grape-sugar, which is soluble. In every seed is a ferment which at the right temperature and moisture can affect this change. The brewer takes advantage of this; he sprouts his barley and corn and lets the young plants turn their supply of starch into grape-sugar; then before the growing embryo can feed on it he raises the temperature and kills the embryo. But suppose the embryo is not killed; then the liquid grape-sugar which the plant has made, flows to every part of it and is by its vital action converted into cellulose, the main substance of which wood is composed. Cellulose has exactly the same composition as starch. Six parts of carbon and five of water make starch; an insoluble, pulverulent powder. Six parts of carbon and six of water make grape-sugar an easily soluble and therefore for the plant, easily transportable, substance. Six parts of carbon and five of water make cellulose, an insoluble substance, strong and durable as oak. Any one who has any penchant at all for

"Admirin' 'ow the world is made."

ought to quite master this adaptation. Starch is an insoluble substance that can be packed away in any available crevice. Properly add one part of water and it becomes solu-

ble and can go to any part of the growing plant. When it gets to any desired part properly subtract one part of water and it becomes tissue, without which the plant as we know it, could not be. Sugar-cane is known nearly everywhere. If it were cut earlier it would contain starch only. Later its sugar would have gone to starch again in the seed, and to cellulose in its cell-walls.

Exercise: Get of your druggist four grains of potassium iodide and one grain of iodine dissolved in an ounce of water. Boil a little starch in water and put a drop or two of the iodine solution in the starch solution; it will turn blue. Now instead of the solution of starch, make a solution by boiling pounded grains of wheat, corn, oats, rye, rice, or bits of tapioca, in water. A drop or two of the iodine solution will turn any of these solutions also blue. Any seeds may be tried this way.

LESSON LXXXVIII.

USES OF PLANTS.

Plants and Food.

Of the three different kinds of food that we require, starch and sugar come entirely from the plant world. Our main supply of fats comes from animals; plants nevertheless furnish us much. Linseed-oil comes from flaxseed. Palm-oil from the palm tree. Castor-oil from the castor-bean. Sweet-oil from the olive. The main supply of vegetable oil comes from seeds. Hickory-nuts contain much oil. Sections of the Brazil-nut under the microscope, show a large percent of oil. Peanut butter is now everywhere a commercial article. The manufacture of cotton-seed oil is a large industry.

What do you know of the beet-sugar industry? Of the sugar-

cane industry? Of "home-made sugar", the maple molasses industry?

The third necessary food-stuff is protein. One main supply is from lean meat, but all sorts of grain give large quantities. The living part of the grain consists entirely of protoplasm and there is always protein stored up as food for the embryo in the seed. The inner cells of a grain of wheat are filled with starch, the row next the bran contains protein entirely.

Plants contain every kind of food necessary for life. Mushrooms consist almost entirely of protoplasm.

Exercise: Put a little of the iodine solution mentioned in Lesson LXXXVII on a bit of mushroom; it will stain it from yellow to brown according as the solution is weak or strong. It stains it the same color as it does your skin. Both are made of protoplasm. Many people eat mushrooms, but as there is a kind that is poisonous, no one should ever eat them unless he *knows* he has an edible variety.

LESSON LXXXIX.

USES OF PLANTS.

Plants and Clothing, Medicine, etc.

How many articles are you wearing now that are made of cotton? Find out how much cotton we raise in a year. Exchange greetings with a school in Georgia and get a cotton plant in return for some northern plant. Read the story of Eli Whitney. Raise cotton from the seed.

Find out from the oldest man in the community all about flax, flax breaking, hackeling, spinning and weaving. Read a description of the hemp industry in James Lane Allen's

"Reign of Law." Study the straw hat industry; at least we know that plants furnish the straw.

It has already been shown that plants furnish us every sort of food we require, sugars, fats and albuminoids. They furnish us also an almost endless list of essences, condiments, stimulants, narcotics and poisons. Among these and in addition to them they furnish us many medicines. Treatises are written on this subject and courses of lectures are given on it in universities and medical schools. We are all acquainted with the use of slippery-elm bark, yellow-root, ginseng, and sassafras as medicines; some parts of many of our common plants are so used; may-apple, wild cherry, poke-root, Datura (jimson-weed), Elecampane, etc. Many organic acids come from plants; citric from the lemon, tartaric from the grape, malic from the berries of the mountain-ash, and acetic from apples, grapes and many other sources. Wood-alcohol comes from beech wood, ordinary alcohol from grains and many other sources, and a large number of other alcohols are derived from plant products. The acids above named often combine with the mineral elements that come up from the soil and form crystals in the cells.

LESSON XC.

USES OF PLANTS.

Lumber and Fuel.

How many kinds of trees grown in your neighborhood are sawed into lumber? How many are cut into shingles? Which are used for fence posts? for telegraph-poles? for barrel staves, heads and hoops? for ax handles? which for mallets and mauls? which are steamed and bent into bushel measures? which are generally cut for fuel? which furnish twigs

for baskets? Gather a bundle of willow twigs. Notice that they are very brittle at the base and break off easily; but that they are everywhere else tough and flexible. We can study the uses to which plants are put and from these we can infer their properties, or we can study their properties and make out from this study the uses to which they may be applied. Which wood is used for furniture, and which is hard and will take a polish and is beautiful when finished, are questions that have the same answer. What forest-trees are most used for shade-trees is one with asking which are the most beautiful or of quickest growth or cast the finest shadow. Let the poplar and oak stand for the houses we live in. The sugar and beech for comfort in the home. The cotton and flax for clothing. The wheat and corn for food. The elm and sassafras for medicine and Whittier's "Palm" is not fable:

"Is it the palm the cocoa-palm,
On the Indian Sea by the isles of balm?
Or is it a ship in the breezeless calm?

"A ship whose keel is of palm beneath,
Whose ribs of palm have a palm-bark sheath,
And a rudder of palm it steereth with.

"Branches of palm are its spars and rails,
Fibres of palm are its woven sails,
And the rope is of palm that idly trails!

"What does the good ship bear so well?
The cocoa-nut with its stony shell,
And the milky sap of its inner cell.

"What are its jars so smooth and fine,
But hollowed nuts, filled with oil and wine,
And the cabbage that ripens under the Line?

"Who smokes his nargileh, cool and calm?
The master, whose cunning and skill could charm
Cargo and ship from the bounteous palm.

"In the cabin he sits on a palm-mat soft,
From a beaker of palm his drink is quaffed,
And a palm-thatch shields from the sun aloft!

"His dress is woven of palmy strands,
And he holds a palm-leaf scroll in his hands,
Traced with the Prophet's wise commands!

"The turban folded about his head
Was daintily wrought of the palm-leaf braid,
And the fan that cools him of palm was made.

Fig. 134.

"Of threads of palm was the carpet spun
Whereon he kneels when the day is done,
And the foreheads of Islam are bowed as one!

"To him the palm is a gift divine,
Wherein all uses of man combine,—
House, and raiment, and food, and wine!

"And, in the hour of his great release,
His need of the palm shall only cease
With the shroud wherein he lieth in peace.

'Allah il Allah!' he sings his psalm,
On the Indian Sea, by the isles of balm;
'Thanks to Allah who gives the palm!'"

Exercise: What plants do for us all the things the palm is said to do for the Indian?

LESSON XCI.

Parasitic Plants.

Many plants cause disease in other plants by growing on or in them and living at their expense. Every one is familiar with the heads of black smut that live on wheat, oats or corn. The

Fig. 135.

a. A section through a branch of mistletoe growing on oak; the mistletoe is to the left, the oak to the right. Mistletoe is a green-leaved parasite, lives on crude ascending sap it gets from the oak's fibro-vascular bundles. Chlorophylless parasites strike through the bark only and live on the living matter of the plant in the cambium layer; *b* shows an end view of Figure 127. *c* is a palmetto brush giving an end view of the bristles (fibro-vascular bundles)

shepherd's-purse that grows everywhere is often infested by a white rust; this same rust grows on radishes and causes the blossoms, seeds and leaves to swell greatly by the multiplication of its organs of reproduction within the tissues of the radish.

Cluster-cups, very beautiful under a low power of the microscope, grow on gooseberry and other sorts of leaves.

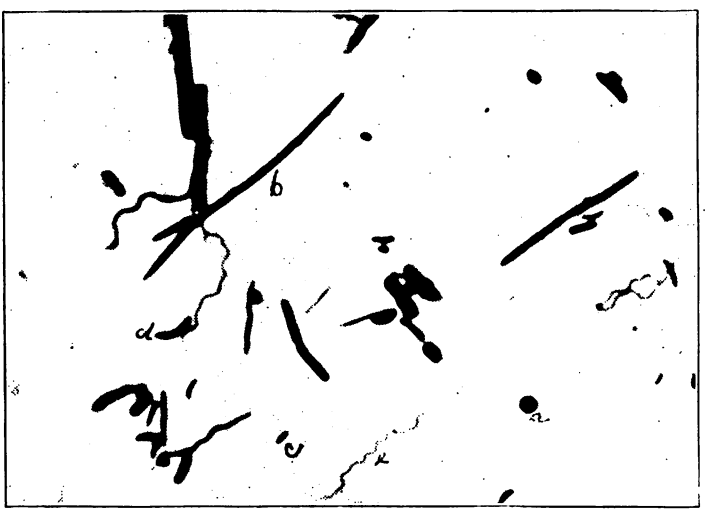


Fig. 136.

Forms of bacteria: *a*, globular; *b*, a long rod; *c*, a short rod; *d*, a bent rod; *e*, a spiral. x 2000.

Lilac leaves are often covered by a grayish powder which is seen under the microscope to be a parasite. Blackberry leaves are often covered with a red rust which is a parasite. A study of these plants requires a knowledge of how to use the microscope, but their large colonies can usually be seen with the naked eye and we should learn how to recognize their presence in this way.

The disease germs known as bacteria, are microscopic

plants. Figure 136 shows four different forms which they assume; they are globular, like *a;* long rods, like *b;* short rods, like *c;* bent rods, like *d;* and spirals like *e*. This photograph was made from tooth scrapings.

Figure 138, shows the bacillus that causes consumption. It was discovered in 1881 by Robert Koch, a German bac-

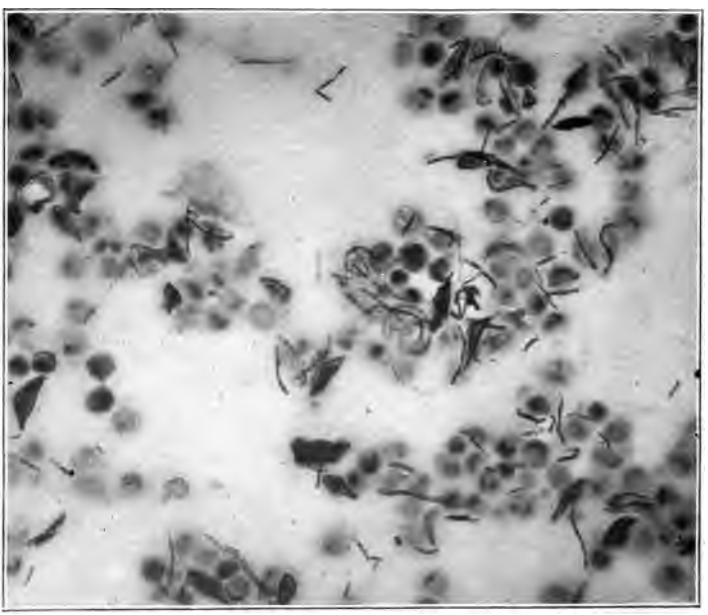


Fig. 137.

Anthrax being devoured by the white blood-corpuscles of a frog. x about 400.

teriologist. He has made it possible for us to make a certain diagnosis of this disease in its earliest stages and in many cases to arrest its development. Some knowledge of his life and labors should be known to every one.

Figure 137 shows the bacillus that causes splenic fever in process of being devoured by the white corpuscles of a frog's

blood. A mouse if inoculated with this bacillus, dies of the disease. A frog does not contract it at all; the reason seems to be that the white corpuscles of the frog's blood eat these bacilli up. This bacillus forms spores when conditions for its living become unfavorable, as when its food begins to give out. These spores are able to resist a degree of heat and cold, which the bacillus cannot; these spores serve it as the spores and

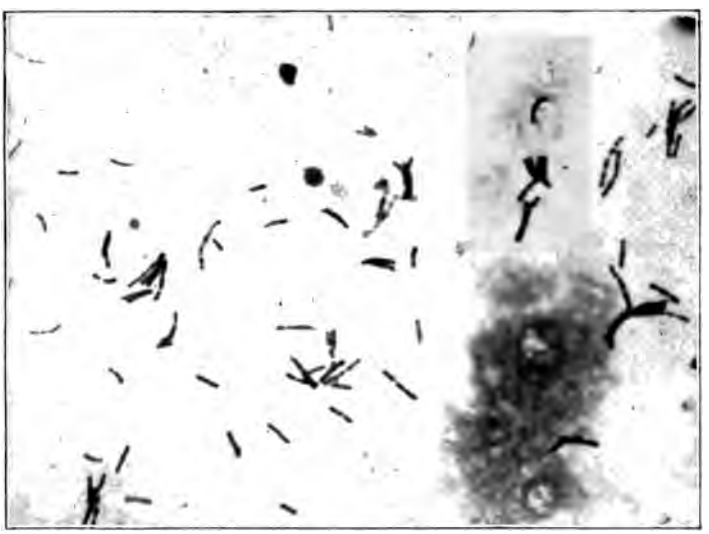


Fig. 138.

The long jointed rods are consumption germs. x 2000.

seeds of higher plants serve them, that is, they enable it to survive extremes of heat, cold or dryness, which the bacillus itself could not. We owe to Pasteur, a French bacteriologist, the conquest of this disease, of the chicken cholera, of the silkworm diseases, and of hydrophobia. It was his work that first gave us the cause of fermentation and decay.

Read the "Life of Pasteur" by his son-in-law, V. Radot.

Parasitic plants should be distinguished carefully from

epiphites; that is, plants which grow on but not into other plants. Epiphites owe support only to their hosts. Parasites owe sustenance also to their hosts. Tillandsia, Spanish moss, so common in Florida, is an interesting example of an epiphite.

LESSON XCII.

The Plant's Chief Work. Saprophytic Plants.

A plant is a machine for storing the energy of the sunlight. We can consume the plant, and its stored energy gives us strength; we can burn it in our fires and it gives us heat, which we can utilize to warm our houses or to do our work or to give us light. Coal is the plant-stored energy of past ages; this distinctive plant duty, the storing of energy, is done only by green plants. Many plants have, however, become degenerate by feeding on organic food and leaving off entirely the storing of sunlight. Mushrooms, Figure 139, are among such plants. They cannot grow on a mineral soil as green plants can. They do not need the light as green plants do. Mucor, the white mould one sees so abundant about stables, on foggy, wet summer days, grows vigorously in the depths of Mammoth cave, where no ray of light ever comes. These plants are destructive; they spend only; green plants are constructive; they make far more than they spend. This is the green plant's mission in the world. They constantly accumulate beyond their own needs what animals and chlorophylless plants spend.

Exercise: Go to a small stream in midsummer a half mile or so below a sewer mouth and note what grows in the water all the way up to and into the sewer. You meet first green and brown algae, scums and microscopic plants; next you see deep blue green plants in large masses; they are Oscillaria, mainly; they often so cover the bottom as to make the water appear

Fig. 139.

"Parasol" mushrooms. Lepiota procera. Photographed by Mr. A. M. Mahaffey.

black. You then find near the sewer's mouth and as far in it as you can see, white streamers that live on the decaying matter contained in the sewer water.

The mushroom and its allies are degenerate plants. They are not doing plant duty. If they live on living plants or animals, we call them parasites. If, like the mushroom, they live on decaying vegetation, or other dead organic matter, we call them saprophytes. The mushroom has chosen the line of least resistance which cannot be chosen by plant, animal or man, except at the expense of its birthright. The oak faced the strenuous life; the mushroom dodged it. Read the introduction to Hawthorn's "Scarlet Letter."

LESSON XCIII.

Chlorophyll.

The general green color of leaves is due to green granules in the cells. Figure 56 shows these granules. They are living bodies; they increase by division just as many low forms of life do. They are simply colored protoplasm. Alcohol will extract their color from them after which they can be stained other colors. The upper side of the leaf is greener than the lower because, for one reason, these granules are far more numerous on the upper side. They are so small that they can be seen with a compound microscope only. They can be well seen in leaves of moss simply by mounting the leaves in water. They can, of course, also be seen in all sections of green leaves or of other green parts of plants. They are very fantastically shaped in some of our commonest green pond scums, Figure 140.

The chlorophyll granules are the starch makers. They sometimes contain so much starch that a solution of iodine colors them so deeply as to mask their green. Starch is com-

posed of carbon and water. These are in some unknown way brought together in chlorophyll granules. The carbon comes from the carbon dioxid of the air. The process is named from three Greek words, which mean a putting together in sunlight, photosynthesis. We ought, sometime, to see these little granules, and find out how incalculably, unthinkably numerous they are in a single tree and to remember that it is to their combined action that the earth's organic upbuilding is due.

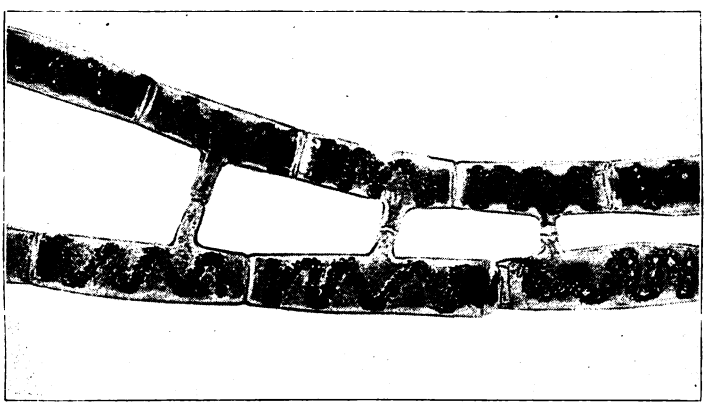


Fig. 140.

Filaments of Spirogyra getting ready for conjugation. The filaments can adapt themselves to the distance between them by length of tube. x about 100.

Exercise: If the following experiment is difficult of performance, nevertheless it will help us to understand how it is learned that starch is made in the sunlight by the green leaf. Immerse a leaf from a potted plant, in Shimper's solution, see below, at about 2 o'clock p. m., and notice that it gives a starch color; the leaf should have been all morning in the sunshine. Keep the same plant in the dark from one morning until 2 o'clock the next afternoon and then immerse a leaf in

Shimper's solution. It will show no starch at all, or very little. Now take a leaf and darken a spot on it between two slices of cork, thus, Figure 141, from 10 o'clock until 2 the next day, keeping the plant all the time in the sunshine. Immerse this leaf as before in Shimper's solution and the starch color will show everywhere except in the spot covered by the cork, which had been in the dark.

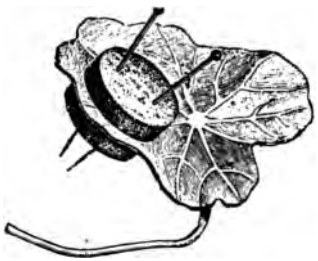


Fig. 141.

Method of shading a spot on a growing leaf between pieces of cork. After Detmer.

Shimper's solution: Dissolve 8 grams chloral hydrate in 5 cc of water and add to this 1 cc of iodine solution; see Lesson LXXXVII for the formula of this solution.

LESSON XCIV.

PROTOPLASM.

Differences between Animals and Plants.

If one considers a cow and a tree the difference is plain enough; one is fixed, the other can come and go; one absorbs liquid and gaseous food only, the other can take solid food into its body and by processes of its own, reduce it to a liquid state; one can live on inorganic food alone, that is, what it gets from the ground, water and air; the other must live on organic food. The plant utilizes and stores the sun's energy; the animals utilize the energy of other animals or plants. The cow has a specialized nervous system. She knows, feels and wills. The tree seems to lack these things. These manifest differences between plant and animal life at their extremes all vanish as we approach the boundary line between them, as we

consider the more similar forms of both. Animals generally require organic food, but so also do all fungi, mushrooms, rusts, smuts, mildews and moulds. Animals generally eat solid food and plants generally do not, but some plants like Venus's fly-trap and Drosera can surround and digest solid food. Plants are generally fixed to the soil where they grow, but so also are many kinds of hydroids, corals, sea-fans, etc., and many kinds of plants move freely at some stages of their lives, as freely as animals do. It has always been true that naturalists could not agree as to whether certain forms are animals or plants. From time to time it is agreed that certain forms hitherto regarded as belonging to one kingdom, shall be set down as certainly belonging to the other. It has often been proposed to have three kingdoms, a plant kingdom, an animal kingdom and a plant-animal kingdom; and this would long ago have been done but for the fact that it would simply have multiplied the difficulty by two; it is now impossible to determine in all cases whether a given form should be called animal or plant; if three kingdoms were recognized it would be impossible to distinguish animals from plant-animals and plants from plant-animals. The impossibility of separating plants and animals except by arbitrary bounds, is one reason why modern science recognizes the term Biology, the science of life.

That the animal moves is probably an adaptation to its food supply, which is, in general, solids that it must go to get.

That the plant is fixed is likewise perhaps an adaptation to the fact that its food-stuffs are liquids and gases that can and do come to it.

LESSON XCV.

PROTOPLASM.

The Respiration of Plants.

It was thought for a long time that plants consume carbon dioxid in respiration and give off oxygen and that animals consume oxygen and give off carbon dioxid. This is wrong, but it is so nearly like something that is right that it is hard to correct. Plants retain the carbon of carbon dioxid and give off oxygen during the day time, but they do not consume the carbon in breathing; they make it into food on which both they and animals can live; they use it in their work of photosynthesis. The part of the plant, however, which lives must consume oxygen. During the night plants give off carbon dioxid as a result of their breathing just as animals do. During the daytime their breathing is disguised by the larger work they are carrying forward; during the day they give off carbon dioxid in respiration, but consume in photosynthesis more than they give off. Plants that are not green and cannot therefore do photosynthesis give off carbon dioxid all day long just as animals do.

Exercise 1. Make lime-water by soaking a pint of lime in two quarts of rain-water a few days. Pour off the clear lime-water and keep it in a tightly corked bottle. Pour a little of this water into a test tube or homeopathic vial, breathe on it and shake it up and it will turn milky on account of the carbon dioxid in your breath. Now soak two ounces of peas by measure, in warm water over night and place them for twelve hours in a six-ounce bottle, well corked. Decant the air from this bottle into a little lime-water as before and shake it; it becomes milky. The sprouting peas give off carbon dioxid also.

Exercise II. To show that chlorophylless plants give off

carbon dioxid, put a growing mushroom in a fruit can, seal it and after a day try the air of the can with lime-water.

Exercise III. Put a healthy potted plant in a fruit can, close the can tightly and set it where it is perfectly dark for twelve hours and test the air in it for carbon dioxid. If it is not put in the dark, carbon assimilation will disguise respiration; but the respiration will not be any the less real because it is disguised.

LESSON XCVI.

PROTOPLASM.

The Cell.

Among the great achievements of the nineteenth century is the discovery of protoplasm and the proof of its identity in animals and plants. Protoplasm has been defined as "the physical basis of life." We can, perhaps, better get at the fact if we say it is the thing that lives, the only thing. Protoplasm makes starch and fat, the cell wall in all its forms and all its varied cell contents. It is a granular, nearly transparent substance; it can surround a bit of food and digest it; it can grow and divide so that what was one individual, becomes two; or what was one cell, becomes two, Figures 143 and 145. Two separate masses can combine so that two cells become one. Figure 140 shows two filaments of a common green pond-scum which have grown passage ways from one to the other through which the contents of two cells can unite; the process is going forward at the top of Figure 147; it is completed at the bottom of the same figure. Protoplasm is sensitive to heat and cold, to an electric current or any sort of bodily contact. It requires food and oxygen to carry on its life processes; it can work in the dark as well as in the light;

indeed most of it is shut up in the more or less opaque walls of plant or animal cells and does its work there; it can carry on the processes of assimilation and excretion. It is contractile; it can slowly move about from place to place when free or it can move about within the cell wall that confines it. It can build cell by cell the oak or the elephant and it is its activities that enable all living things to do whatever they can do. It can surround itself with a wall of wood, of phosphate of lime as in bones, of silica. Goethe, who explained so well the transformations of the leaf, thought there must be somewhere a type plant by the modification of which all plants are made. This type plant, "Urpflanze," as he named it without seeing it, is the typical plant cell. When he sat in his gardens and talked about them but could not find them, millions of them clothed his trees from root to crown, for the green coating on bark and fences in damp countries and localities often consists almost entirely of them. Multiply them enough and modify them enough and the miracle of the vegetable world is all about us; and cells in the presence of the proper stimuli can be shown to be able to do this multiplying and modifying.

LESSON XCVII.

HOW PLANTS MULTIPLY.

The Asexual Way.

Go first to the strawberry and see the runners, prostrate stems that grow out along the ground and take root at a suitable distance from the parent stem. This is one way that a plant can become two. Figure 142 shows a similar mode of

multiplying in the water hyacinth, a plant found in abundance on the St. John's river in Florida. The petioles of the leaves swell out into large floats (a) and by their number and arrangement keep the plant upright and prevent it from sinking. The runner has sent roots down into the water six inches away from the parent plant. This plant has so spread over St. John's river as to seriously interfere with navigation

Fig. 142.

Water Hyacinth. See text.

and the government has made an appropriation for the year 1903 for the purpose of stamping it out.

Go next to the raspberry, or if you know it, to the walking-fern; the raspberry bends its tip over to the ground and the fern its to the rock wall on which it grows and they alike take root at a distance from the home-plant and one becomes two. Cut off a number of limbs from a willow and plant them along a stream; they will grow into trees. Are they new trees? Individuals? If they had grown on the old stem would

they have been new trees? Is a tree a colony? Budding consists in taking uninjured buds from one tree and planting them under the bark of another tree. Grafting consists in taking little shoots from one tree and properly planting them in the limbs of another. Suppose wine-sap, bellflower and five other varieties of buds are planted on the seven limbs of a seedling and grow into thrifty, fruit-bearing branches; what

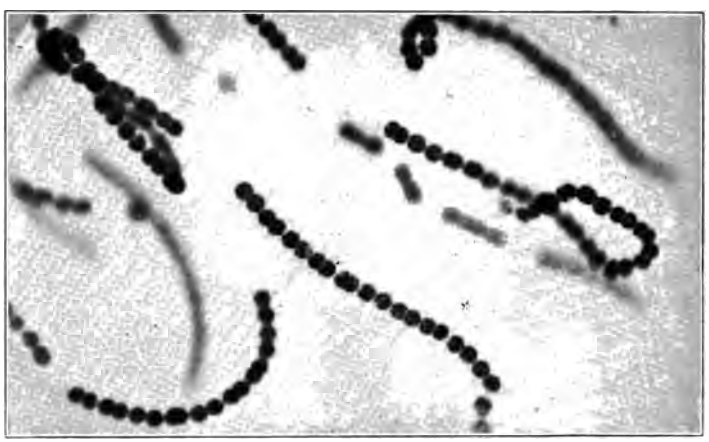


Fig. 143.
Filaments of Nostoc, a blue-green alga in process of cell division. x 400.

sort of tree is this? Is it seven trees? Is every bud an individual in the colony that goes to make up a tree?

There are many one-celled plants that have only this asexual way of multiplying. Figure 143 is a blue-green alga that may be found in gutters, often along the street or damp places in greenhouses; it is called Nostoc. The cells of the filament here shown are in several stages of division. Figure 145

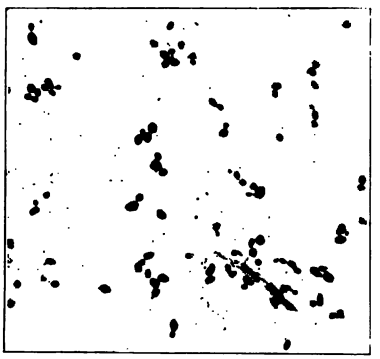


Fig. 144. Yeast-cells in process of budding See text. x 200.

shows a parasitic plant that is often found in sores on the body; it is often coughed up by patients suffering with sores on their lungs. Several stages of cell division can be seen.

Yeast owes its properties to a one-celled plant that lives and grows in suitable liquids. The yeast-plant has a peculiar way of dividing, called budding,

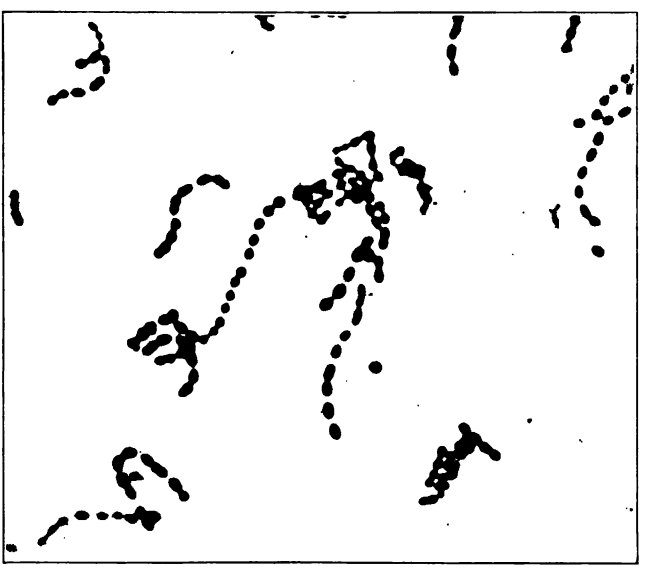


Fig. 145.

Filaments of Streptococcus dividing. The kinship in form of Nostoc and Streptococcus is one good reason for regarding bacteria as degenerate plants. Highly magnified.

Figure 144; a very small bud appears on one side, which grows until it is as large as the mother-cell. It is called the daughter-cell; in actively "coming" yeast it often happens that a daughter-cell begins to bud before it separates from its mother. This is true of a granddaughter and great granddaughter-cell also before any of them have let go, so that it is possible to get four or five generations in one picture.

LESSON XCVIII.

HOW PLANTS MULTIPLY.

The Sexual Way.

Fig. 146.

Reproduction by cell union on neutral ground; no distinction of male and female.

Another very different mode of reproduction is by the union of two cells one of which is known as the male cell and the other as the female. Figure 146 shows two exactly similar plant cells uniting on neutral ground. This is the simplest possible sexual multiplication. The new individual formed by their union will divide many times asexually to form new generations. In this instance it is not possible to say which is male and which is female, for both look and act exactly alike.

Figure 147 shows two cells uniting, but not on neutral territory. The cell contents of all cells in the left filament pass entirely through the funnel tube to the right filament. Both cells help make the *connecting tube;* they look alike, but do not act quite alike; there

is physiological, but not anatomical, distinction of sex; the left filament is the male filament. The egg-shaped bodies in

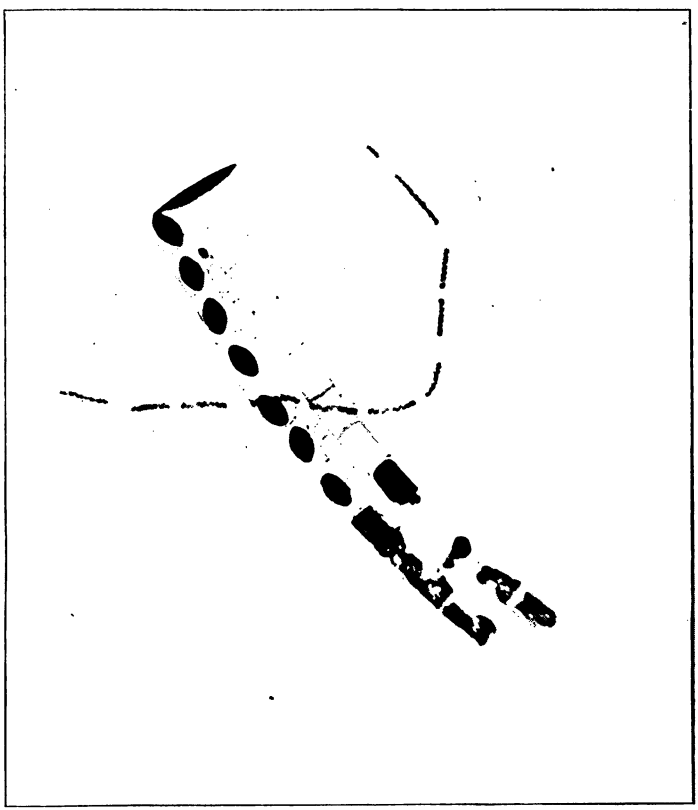


Fig. 147.

Spirogyra. Reproduction by cell union in the home of the female cell; physiological distinction of sex, not anatomical; the filaments look alike. x 200.

the female cells are new one-celled plants; the parent cell walls will decay and after a rest these will all grow by division into new filaments of pond-scum.

Fig. 148. Oedogonium, a common green alga attached to sticks and stones. 1. the small motile male cell goes to the large female cell. 2. Anatomical and physiological distinction of sex. After Oltmans.

Figure 148 shows male and female organs of a plant in which there is anatomical, as well as physiological, distinction of sex; here the female cell not only stays at home and awaits the coming of the male, but it is larger, better fed and better housed.

Any number of illustrations could be added showing progress in dissimilarity between the male and female cells. This difference is in size, the male being the smaller; in activity the male being the more active; in protective coverings

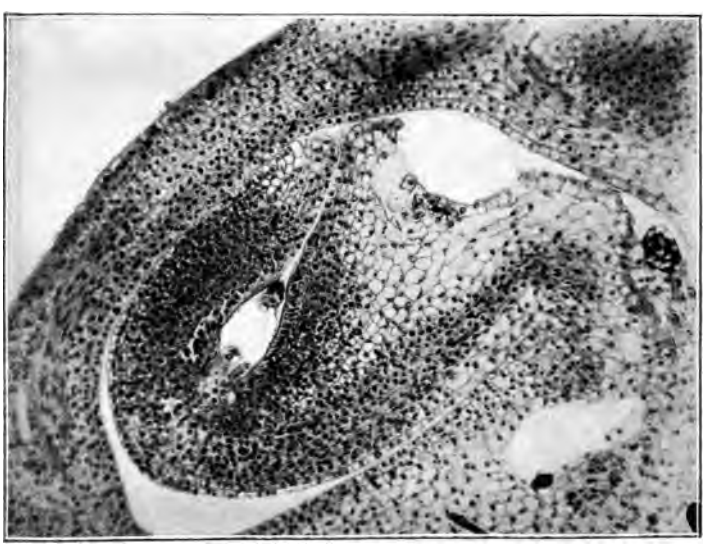


Fig. 149.

Section through the well-protected, well-fed home of a female cell of Erigenia. The section is through the micropyle through which the male nucleus enters. Slide prepared by Mr. Charles H. Frazee. x 100.

Fig. 150.

Cross-section of the summit of a male moss plant. *a*, an antheridium containing sperm-cells. x 200.

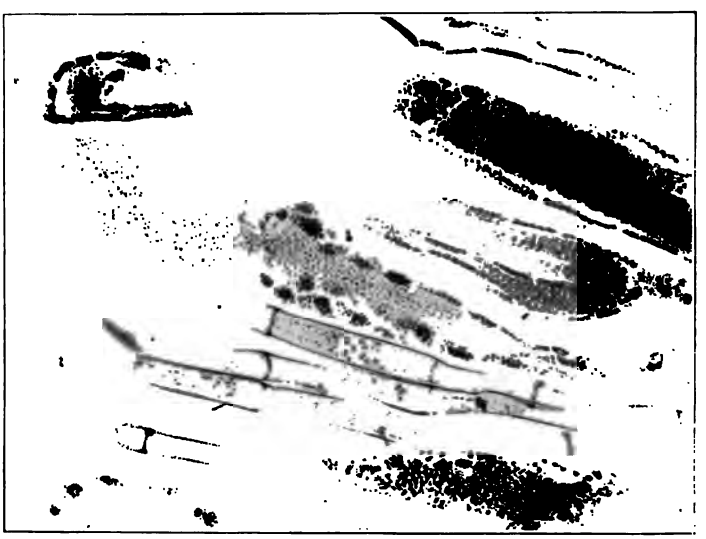


Fig. 151.

The same as figure 150, with antheridium discharging sperm-cells. x 200.

and mode of nutrition, the female being the better cared for and better fed. Figure 149 shows the safe and well lardered house of the female cell of the harbinger-of-spring, Erigenia

Fig. 152.

Two sperm-cells of moss very highly magnified. After Atkinson.

bulbosa. Figure 150 shows the summit of a male moss stem. (a) is a longitudinal section of an antheridium containing sperms. Figure 151 shows an antheridium bursting and discharging the sperms. A simple sperm, when mature, resembles Figure 152. This swims by means of its cilia into the archegonium of the female moss head which closely resembles Figure 153. It reaches the egg-cell at the bottom of the archegonium, and fertilizes it. It will be seen by these figures that among mosses the differences between the egg-cell and the sperm-cell are very great.

Fig. 153.

Archegonia of a liverwort, Marchantia; 1, an almost longitudinal section through the entrance; 2, passes through an egg-cell. These are very similar to the same organs in moss. x 200.

Figure 154 shows at (a) the fertilized egg-cell of the harbinger-of-spring.

All higher plants, mosses, ferns and flowering plants produce in one way or another and at one time or another in their life

history, such a fertilized egg-cell, and from this cell new plants grow.

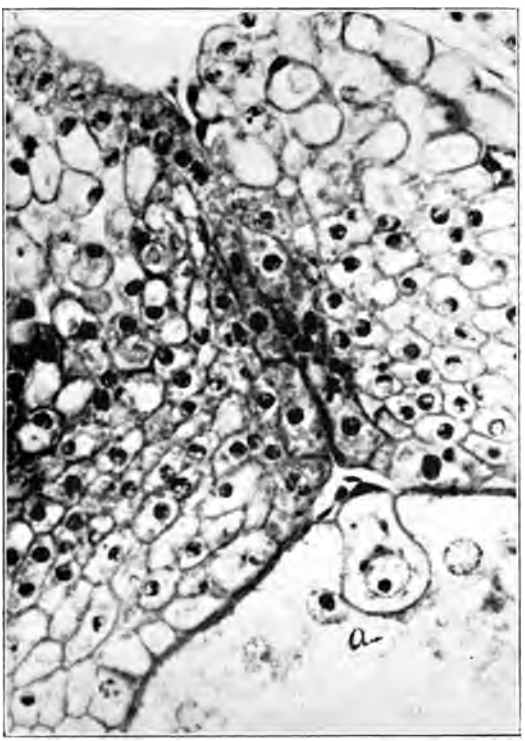


Fig. 154.

A section of a young plant of Erigeniabulbosa during the resting stage after the egg-cell had been fertilized. Slide prepared by Mr. Charles Frazee. x 750.

Figure 155 shows a young embryo of a smartweed; the fertilized egg-cell has divided twice so that it now consists of four cells. Figure 156 shows a stage considerably more advanced. It is thus by cell division, unequal growth, in different parts,

unequal growth in the cells themselves, and the development of walls of varying thickness and quality, that the plant with its organs and tissues is matured.

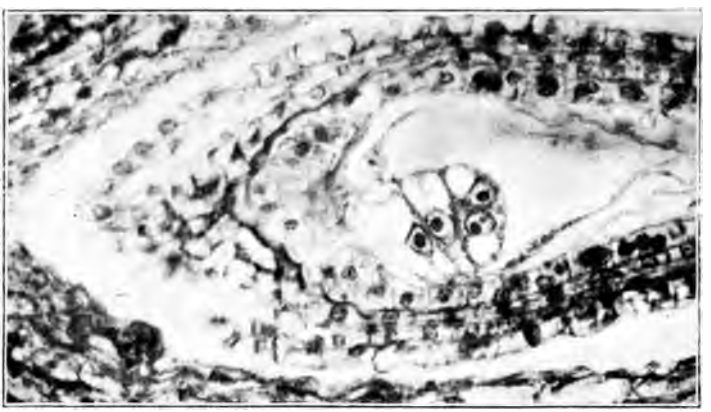


Fig. 155.

A young smartweed after the fertilized cell had divided and the two resulting cells had again divided. Slide prepared by Miss Ruth Trueblood. x 750.

It is worthy of note that the pistil which houses the female cell, the macrospore, grows at the center of the receptacle, in the direct line of the food supply; the stamens always grow to one side and are accordingly, never so well-fed; they often grow on the sepals or petals or even on the ovary itself, and must be content not only with a side flow of sap, but they must share this side flow.

A fine study for any one with a microscope would be to determine the relative amount of conducting tissue that leads to a stamen and a pistil. To get the real ratio, these amounts should then be divided respectively by the number of pollen-grains the stamens bear and the number of seeds the pistil can bear.

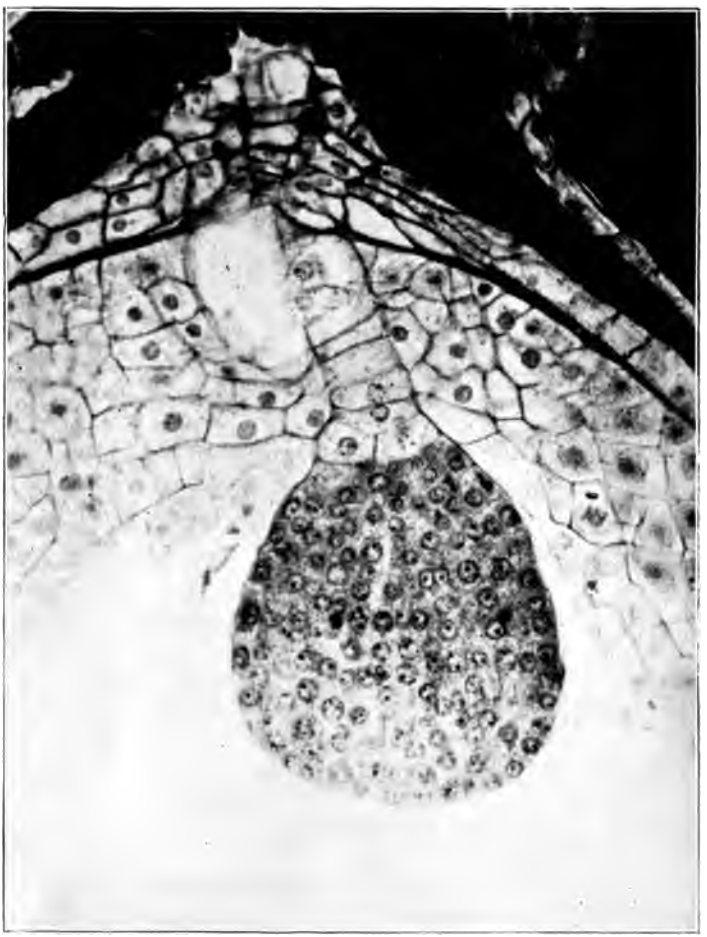


Fig. 156.

Many-celled stage of a young plant of twinleaf. Slide prepared by Mr. Charles Frazee. x 750.

LESSON XCIX.

Growth from the Cell to the Tree.

Cells have been shown in process of division. Sometimes they divide in one plane only and we have then a filament like Figure 143. Sometimes they divide in two planes only and we have flat plants of varying length and width but only one cell thick. Some moss leaves, except in the region of the veins are such structures. Sometimes cells divide in three planes and then we have figures of varying length, breadth and thickness like most of the plants we know. The almost infinite variety of shapes in plants arises from two causes. First, the cells divide in their different planes a different number of times, many divisions in one plane, giving length, fewer in another giving breadth, and fewer still in the third, giving thickness. Second, the cells themselves have three dimensions. They are solid bodies and they may grow to have very varying dimensions. The typical plant cell is globular, all its dimensions are the same. Plant cells vary in their shapes from this typical form so much that their shapes could not have been conceived of or believed to be if they had not been seen. The various accompanying microscopic figures show other cell shapes.

LESSON C.

Cell Duties in a Many-Celled Plant.

In a one-celled plant its life processes are all carried forward by the one cell. It must breathe; it must assimilate; it must construct a wall if it has one; it must store up food; it must contract if it is to have voluntary motion; it must re*produce.* As soon as cell union comes, with a vital union be-

tween two or more cells, these duties can be divided out among many or fewer different cells; a tree for example, has protective tissue, the bark, some cells of which do nothing else; it has conductive tissue that distributes sap to all parts. It has supporting tissues that discharge no other duties than that of holding the vital parts in position. It has secreting cells such as produce the milk of the mulberry, the resin of the pine, the nectar of the flower, etc. It has storage cells for starch, fats, crystals, etc. It has assimilative tissues and reproductive and many other sorts. This division of duties can be but slight in one-celled creatures. It can only be between different parts of the same cell which is generally too small to be seen by the naked eye. Cell union has its advantages and disadvantages. In Nostoc, and other similar filaments each cell is independent except for purposes of defense and buoyancy. It is a sort of defensive alliance that leaves every member of the community free to manage its own internal affairs. The community life in Spirogyra has for its advantage the extra protection and support of the common wall. The disadvantage is that individuals are subject to the accidents of the colony. If we could study all plants gradatim from the simple one-celled Protococcus to the oak, we should find very gradual steps in the formation of what may very fairly be called the combined trusts that go to make the oak. The root trust gathers the food containing moisture from the soil and hands it on; it also holds the oak in place and lends its reservoirs as storehouses. The plant has so completely given over these duties to the root that it is dependent on it for at least two of them. The chlorophyll is a trust for storing the energy of sunlight so complete that no other part of the plant can take its place even partially or temporarily. The great advantage of these combinations is without question; because all the plants which are large enough to be seen by the naked eye have adopted them, and the higher the plant in the

life scale the more complete, numerous, and complex are these combinations. Plant organization has been long ages in perfecting the division of labor and the co-ordination of its tissues and organs. Society's organization may one day be equally just and perfect.

LESSON CI.

Young Plants.

Every one has noticed the difference between the green gosling and the white gander, which it becomes. A chick does not much resemble a chicken. There is a difference of like meaning and importance between young and old plants.

Exercise I: Plant cucumber, squash, pumpkin, and several kinds of muskmelon and watermelon seeds. As soon as they come up if you see any remains of the seeds remove them and try to tell by the young plants what each one is. Try when they have only two leaves; try again when they bear four leaves. Watch them as they grow. Visit patches of all these things growing in the field and see if you can distinguish them. You will learn by this exercise that young plants resemble each other much more than old ones.

Exercise II: Gather mulberry leaves from a large tree, but not on vigorous young shoots. Gather other leaves from young trees. The leaves on young trees are lobed; on old trees they are not.

Exercise III: Learn to tell several varieties of oak by the leaves. Try now to determine these several varieties when they are not more than a year or two old, and it will be clear that the young does not resemble the old and that the young of different species closely resemble each other.

Exercise IV: Take the most irregular flower you can find, *a larkspur for* instance, or locust, or bean blossom. Learn the

shapes of all the petals of the adult flower. Now examine the petals in the bud. The lesson is the same, young petals resemble each other.

Exercise V: Notice the branching of a soft maple, called also a silver maple; its branching is deliquescent like that of the elm. Notice the branching of the sugar-maple; it is excurrent like that of the fir. Now find a young soft maple and you will find that its branching is excurrent, like the sugar-maple's. You will learn from this lesson that the young of one species sometimes resembles in one or more particulars the adult of another species. These are useful lessons in the science of embryology. It has been found out as a principle that the growing young that resemble each other longest are the nearest akin. Try your watermelon, two varieties of muskmelon and cucumber seeds again and see how old they are when you can easily distinguish the watermelon from the rest. How old are they when you can distinguish the cucumber? How old when you can distinguish the two varieties of muskmelon?

It is more than suspected when the young of any dominant species resembles the adult of another species that the first species is higher in the life scale; young frogs, tadpoles, resemble fish, which are lower in the life scale; young butterflies, caterpillars, resemble worms, which are lower. At any rate it will be valuable to observe carefully the plants you study at all available ages. Do all the "baby bean" work over again from these points of view.

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